# TEST & REPORT OF A MODERN ICE PLANT

K. HEIM
J. E. FITCH
C. H. JONES
G. HIRSCHFELD

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ice plant

# TEST AND REPORT

OF

# A MODERN ICE PLANT

## A THESIS

PRESENTED BY

Karl Heim

Charles H. Jones

Joseph E. Fitch

George Hirschfeld

TO THE

PRESIDENT AND FACULTY

OF

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stations, and, although it cannot be said that any of the plants are out-of-date, still there are a few which do not possess all of the modern equipments of the stations which have been lately installed. It has been our good fortune, to have at our disposal, one of the most modern ice plants in the country, namely, the Edgewater Plant of the Knickerbocker Ice Company. Not only have we had the free use of all the machinery and boilers in the entire station, but we have also been given the heartiest cooperation in all of our work, by the Chief Engineer in charge, Mr. Benjamin M. Kirker, whose untiring willingness to assist and explain, has greatly added to making this work what it is

The Edgewater Plant was built in the early part of the year 1907. The York Manufacturing Company furnished all the refrigerating machinery, and supervised the entire erection of the station, while Messrs. Postel and Linn, the eminent Chicago consulting engineers, designed the plant. The building, which is two stories high, and over a half block long, is located on Evanston Avenue between Foster and Berwyn Avenues, and faces west. The first provision in selecting a site for this plant was to get it located near to a railroad in order that coal might easily be obtained and the ice shipped away. As a consequence the station was located on the Chicago, Milwaukee and St. Paul Railroad, from which three tracks run into the yard. The

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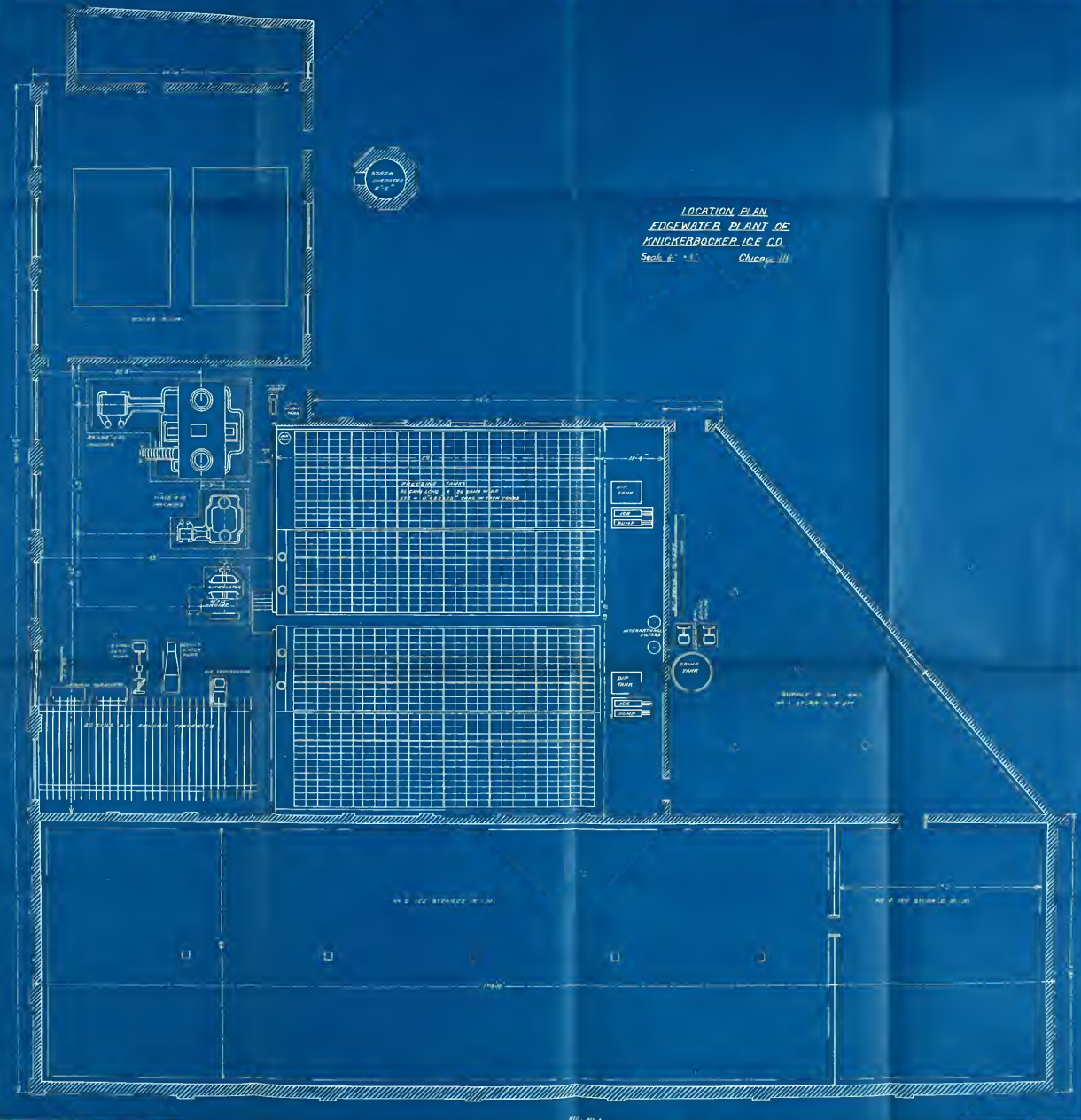
LOCATION PLAN
EDGEWATER PLANT OF
KNICKERBOCKER ICE CO
Chicago Ill
STACK
FREEZING TANKS
DIP TANK
ICE
PUMP
INTERNATIONAL FILTERS
DRIMP TANK
DIP TANK
ICE
PUMP
AIR COMPRESSORS
ICE STORAGE
ICE STORAGE

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entire plant is built of brick, with cement floors, both in the boiler and engine rooms. The most noticeable feature of the entire plant is its simplicity. Each room and its machinery has its special function in the ice-making process, and the entire cycles of sweet (distilled and treated) water, coal, cooling water and ammonia can easily be followed.

MANUFACTURE OF THE ICE.

All of the ice made at this plant is manufactured from the exhaust steam of the engines and pumps. The main object of the Knickerbocker Ice Company in their process, is to get the ice as pure as it is possible to get it. On account of this the water is filtered and refiltered and softened, in order to get as good results as they can, under the conditions existing in the plant. The sweet water which is used in making the ice is tested daily by the Chief Engineer, for hardness, causticity, and alkalinity, and if his results prove unsatisfactory or abnormal, the charges of lime and soda in the Kennicott Water Softener are changed. A complete list of contents of the testing cabinet, and normal results for the testing of the water are recorded on an accompanying page.

The exhaust steam from the engines and pumps, is piped to a main underneath the main floor, from which it is brought to the mezzanine floor through a specially

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designed York oil separator, installed for the purpose of removing all the grease and oil from the exhaust steam, obtained from the cylinders of the engines. From the separat--or the exhaust is piped to 2 Worthington Surface Condensers, each of which has 500 square feet of condensing surface. The average temperatures at which the cooling water enters and leaves these condensers are 78 and 120 degrees Fahrenheit respectively. The steam after being condensed is drained to a float trap or oil skimmer, from which a 6½"x 4 3/4"x 6" Snow pump, forces the sweet water to the reboiler. The reboiler room, 30' x 16' x 9', is on the floor above the mezzanine, and contains the reboiler. This is a large metal-lined tank 24 feet long and 4 feet wide fitted with steam coils, and supplied with a patent regulator and skimming device, which may be adjusted from th second floor. The sweet water after being reboiled and separated from some more of the oil, now flows by gravity to the cooling pipes or flat coolers. The sweet water is cooled here by flowing through double tube pipes, the water being cooled by well water, flowing in the other direction. The cooling water is obtained from a well underneath the plant, about 400 feet deep, although the pumping is done only from a depth of 225 feet. A W.B.Erb Double Acting Deep Well pump having a stroke of 24" with a 8½" pipe attachment, top and bottom, and a capacity of 2.48 gallons per revolution, and running

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at 20 revolutions per minute is used.

The sweet water flows through 6 double pipe cooling coils, 12 pipes high by 17 feet long of 2" and 1¼" galvanized piping. After the water has been cooled it flows through charcoal filters of the Standard York type, of which there are 8 in this station. In order to insure very good filtration the water is passed through a set of 4 of them and then is refiltered in the remaining 4. From the eight filters the water is discharged into a 19' x 8½' x 6' storage tank on the mezzanine floor, which is provided with a direct expansion ammonia coil, the tank being made of ¼" iron. From the storage tank the sweet water is drawn through a centrifugal water pump, made by the Platt Iron Works, and direct-connected to a 1 Horse Power - 220 Volt 3 Phase Induction Motor. This pump agitates the water in the storage tank, and forces it through coils of the double pipe style, employing the direct expansion of the ammonia gas, for cooling the water still more. After passing through these pipes the water is forced through #5 International Paper Filters, 2 of which are installed in this plant. The water is then delivered to the automatic can fillers and into the cans where it remains until frozen. The amount of water entering the cans is controlled by patent regulators. After the cans have been filled with water they are

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# 1½" SINGLE STAGE MOTOR DRIVEN TURBINE PUMP.

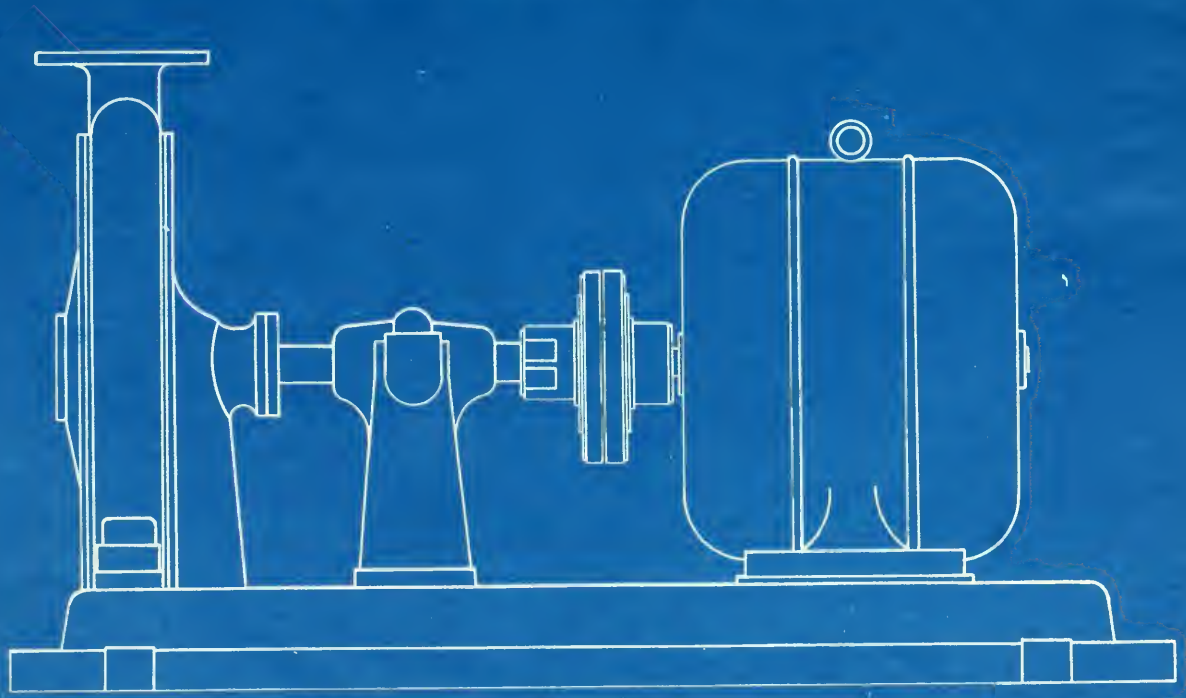

FIG. No 2.

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lowered into the brine, which surrounds the ammonia expansion pipes, and allowed to freeze. The average length of time it takes to freeze a can of water is approximately 48 hours. Freezing cans used in this station are 11½" x 22½" x 56", each making 400 pounds of ice; the capacity of the plant being 1350 cans. After freezing the cans are removed by means of pneumatic hoists, the compressed air being furnished by a 11 x 11 x 12 Westinghouse Air Compressor, of the Locomotive Type. The cans are then transferred by means of a traveling crane, to the east end of the freezing room, where they are lowered into dip tubs of warm water to loosen the ice from the sides of the can. The ice is then removed by placing the cans in the dumps, which tumble them and allow the ice to slide through chutes into the storage rooms.

THE FREEZING ROOM.

The freezing tanks are 2 in number, made of 0.25" steel, each being 62½' x 30.75' x 5½', and containing 40,000 feet of 1½" ammonia piping, placed in vertical sections between rows of cans; the tank is fitted to accomodate 676 ice cans. Each tank is divided in the center by a partition running the full length of the tank, with an opening at the top at one end, and at the bottom of the other for the circulation of the brine.

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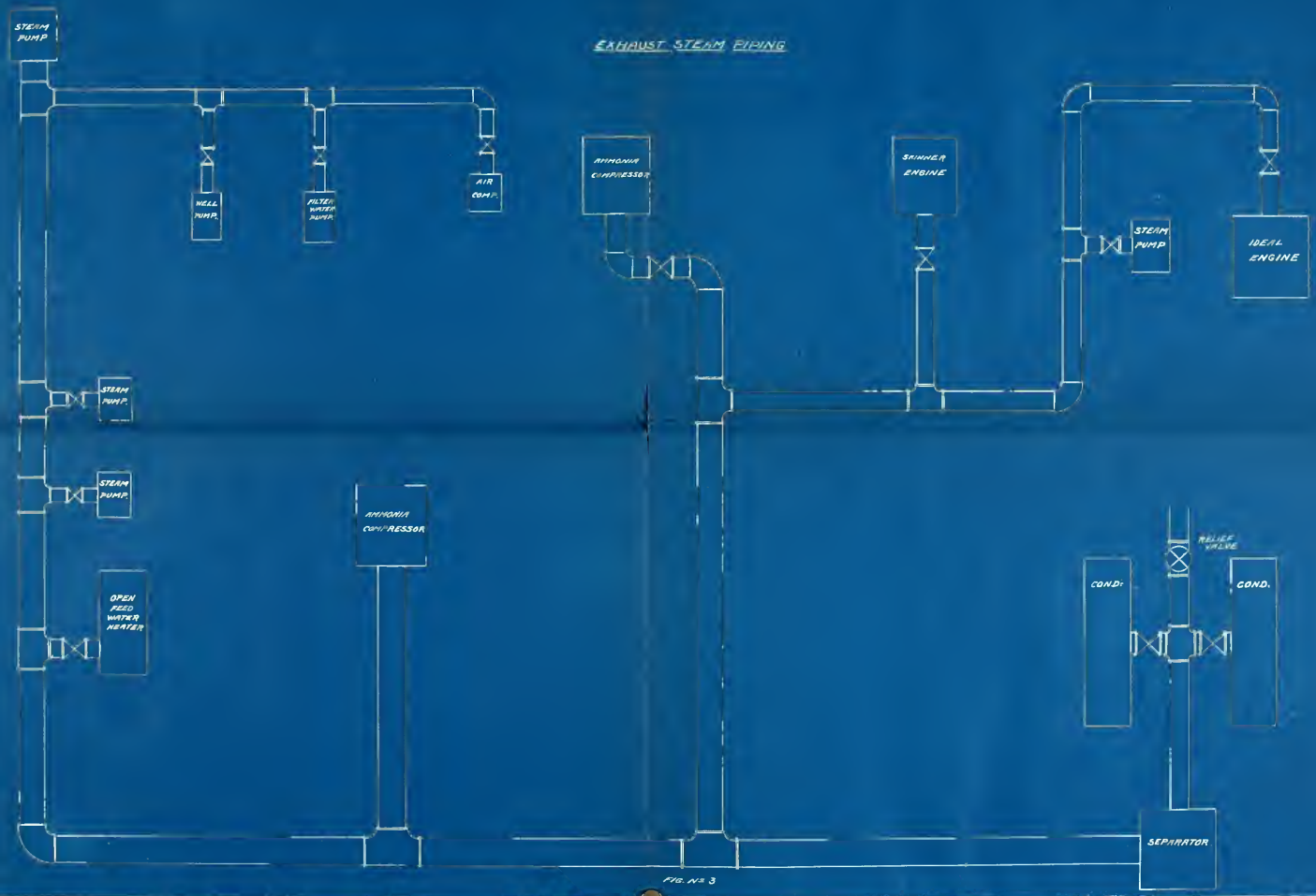
EXHAUST STEAM PIPING
STEAM PUMP
WELL PUMP
FILTER WATER PUMP
AIR COMP.
AMMONIA COMPRESSOR
SKINNER ENGINE
STEAM PUMP
IDEAL ENGINE
STEAM PUMP
STEAM PUMP
AMMONIA COMPRESSOR
OPEN FEED WATER HEATER
RELIEF VALVE
COND.
COND.
SEPARATOR

FIG. N° 3

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# FILTERED WATER PIPING DIAGRAM.

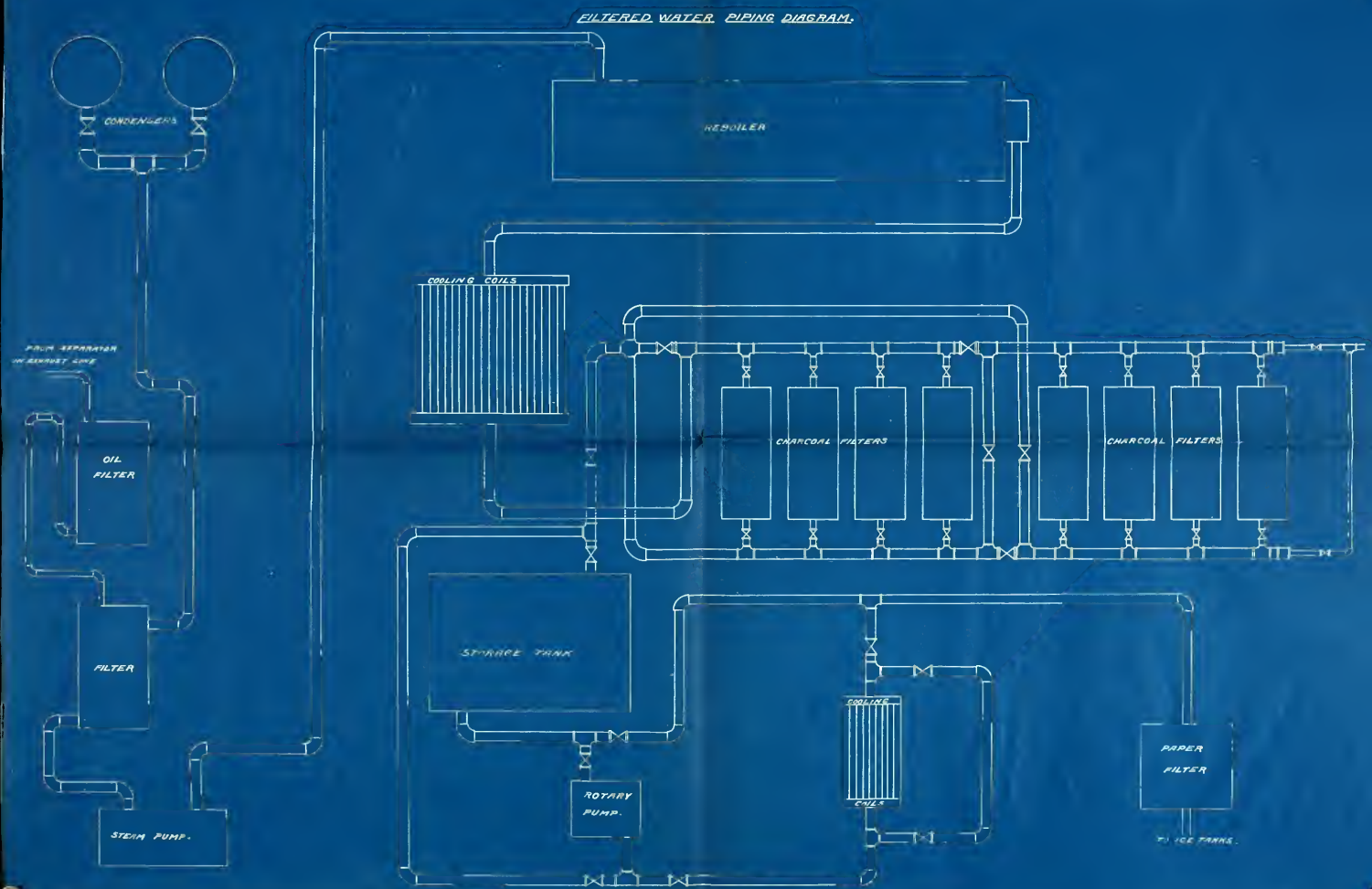


FIG. Nº 4.

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# COMPRESSED AIR PIPING

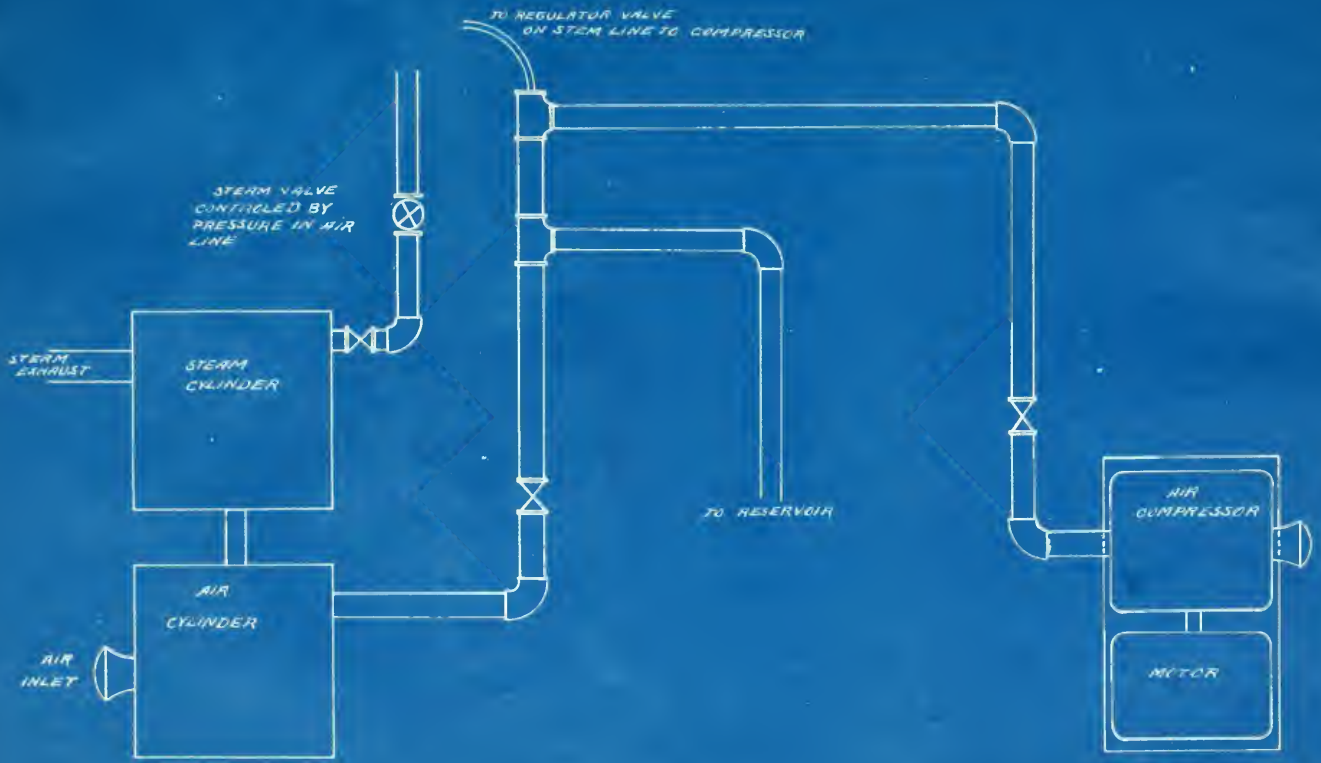


FIG. NO 5

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From the receivers the ammonia is allowed to flow through a back pressure or pressure regulating valve into a series of ammonia coils surrounded by brine. The pressure on the ammonia is reduced in these coils and the ammonia in expanding takes the necessary heat, for the physical change, from the surrounding medium. Inasmuch as ammonia boils at a temperature of 28 degrees below zero, a very cold temperature is realized.

The gas, as it leaves the expansion coils, is drawn into two gas compression pumps of the improved vertical single-acting type, 24 inches bore and 36" stroke, fitted with cooling jackets, and properly lagged. The pumps are fitted with special ammonia stop valves. The gas, after passing into the compressors at a pressure of 15#, is compressed to about 150#, and is then forced through an oil trap into the ammonia condenser or cooling coils, which consist of 28 stands of the double pipe type, 1.25" and 2", 12 pipes high by 19 feet long with rewash headers. Their capacity is 350 tons refrigeration of water at 80 degrees Fahrenheit. The inner pipe of these coils, contains the mixture of well water and city water. The outer pipe contains the ammonia gas, which has become greatly heated, by being compressed and must now be cooled.

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In the York system of refrigeration, which is employed throughout the plant, the directions of the flow of the cooling water and the ammonia through the pipes are opposite, by which arrangement the greatest efficiency is obtained. When the gas has become sufficiently cooled by the water it is condensed into a liquid and drained to the receivers, from which the ammonia goes through the same process. In order that the ammonia gas is perfectly free from oil, which is used for lubricating the compressor cylinder, it is necessary to employ oil traps, as stated above, especially designed for the purpose of removing all entrained oil. For this purpose two oil traps, one on each discharge line from the compressor are used in this station. One of the attractive features in all of the ammonia and steam piping, is the thorough system of pipe insulation. All the lines are insulated with Keasbey and Mattison 85 per cent magnesia pipe covering, which insures minimum loss by radiation.

SERVICE OR COOLING WATER.

The cooling water used in this plant is obtained, both from the 400 foot well, before mentioned, and from a 4" city supply pipe. Two service pumps are employed alternately, for circulating the water through the cooling coils, condensers, and over the cooling

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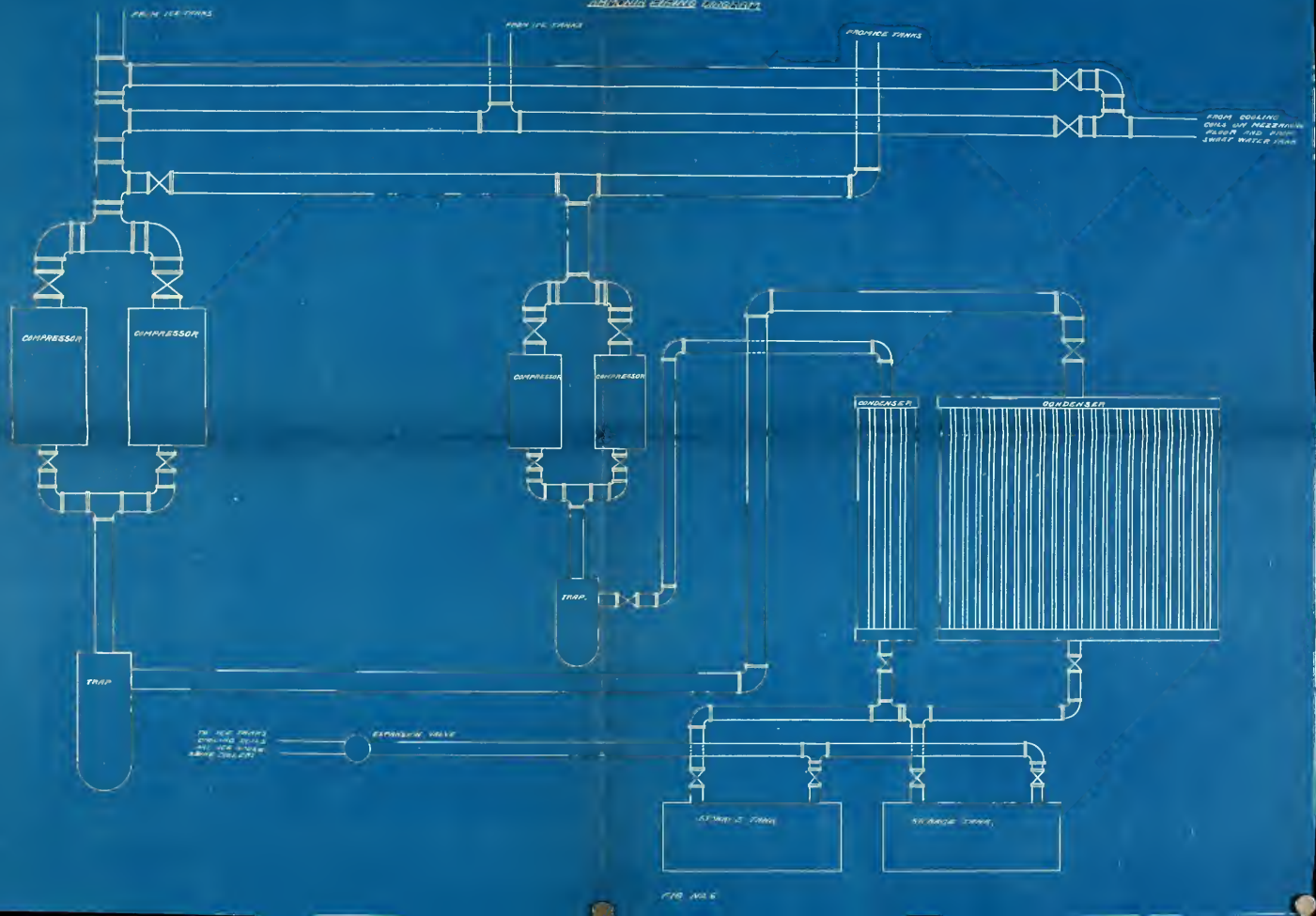
AMMONIA PIPING DIAGRAM
FROM ICE TANKS
FROM ICE TANKS
PROVISION TANKS
FROM COOLING COILS IN MEZZANINE FLOOR AND FROM SWEET WATER TANK
COMPRESSOR
COMPRESSOR
COMPRESSOR
COMPRESSOR
CONDENSER
CONDENSER
TRAP
TRAP
EXPANSION VALVE
TO ICE TANKS COOLING COILS AND ICE WATER COOLER
STORAGE TANK
STORAGE TANK
FOR NO 6

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tower. Either one of these pumps is sufficiently large to do the work, but one is held in reserve for cases of emergency. The reciprocating pump is made by the American Steam Pump Company, and is of the Marsh Type, 10½ x 14" x 20", with 10 inch suction and 8 inch discharge connections. A 4" riser carries the cooling water to the flat coolers, where the temperature of the sweet water is lowered. The other pump is of the 2 stage Centrifugal type, made by the American Steam Pump Company, with 7 inch suction and 6 inch discharge connections. The pump is direct connected to a 3 phase 60 cycle, 240 volt, 40 horse-power Fairbanks-Morse induction motor, which is provided with a separate starting box. The cooling water,which is maintained at a pressure of 40#, after passing through the ammonia condensers, sweet water coolers, and through the steam condensers, where its temperature is raised from about 80 to 130 degrees, it is forced to the roof of the building through a 10" riser, and into a trough 240' x 4' x .833', which has a slope of one foot in eighty, and is allowed to pass over the cooling tower.

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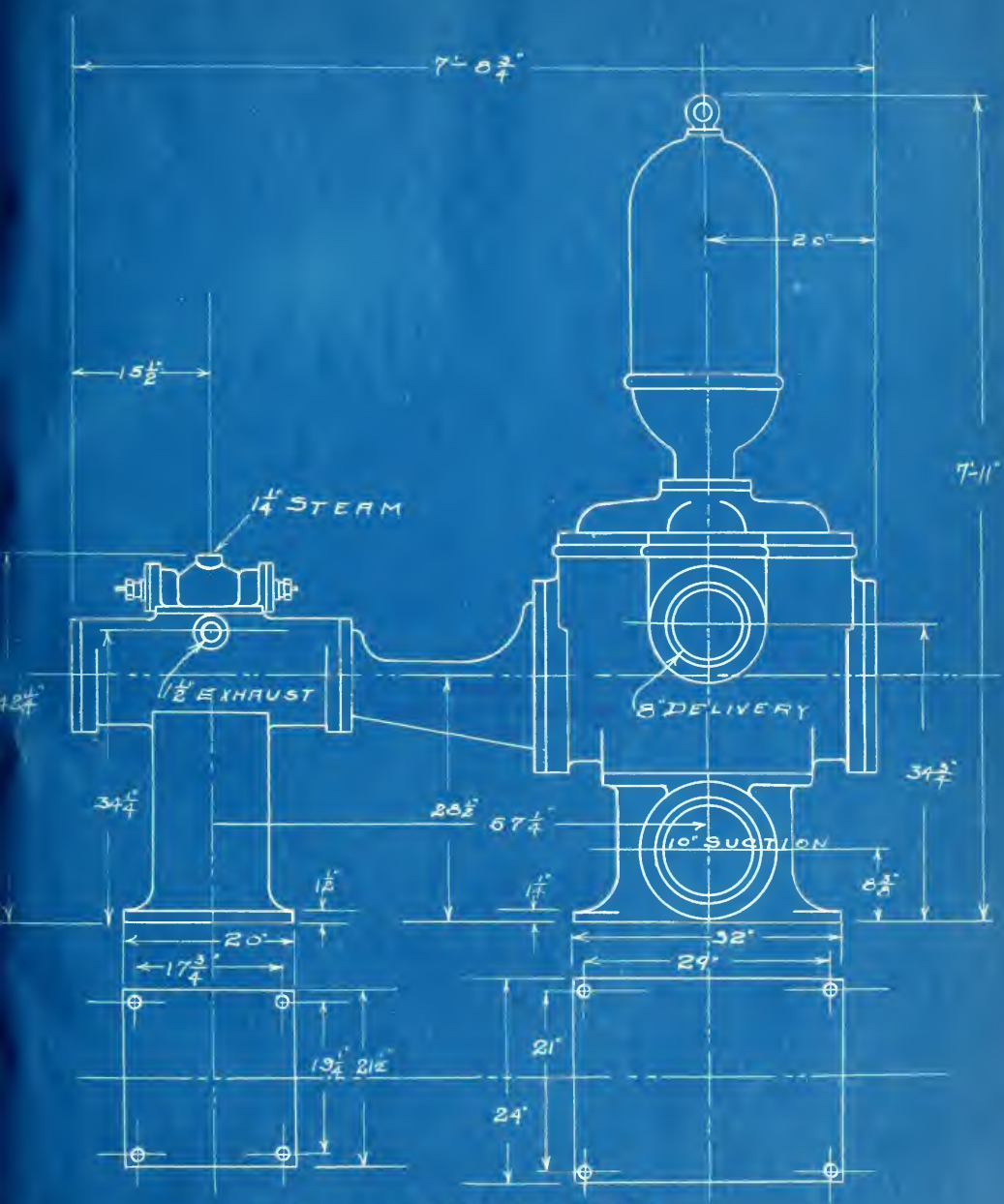


MARSH LIGHT SERVICE PUMP
SIZE 10X14X20

FIG. No 7.

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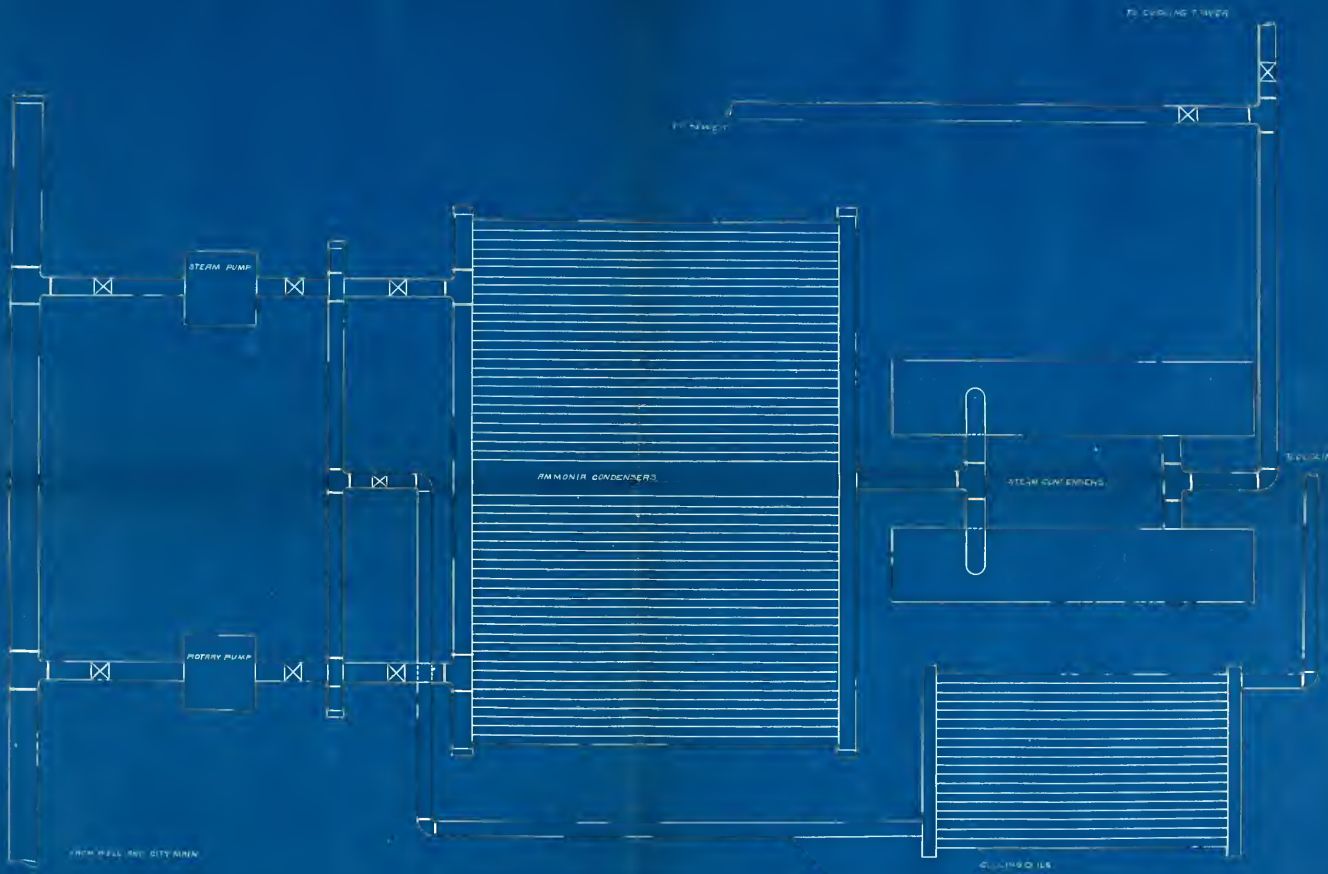


COOLING WATER PIPING

FIG. No. 3.

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Part of the cooling water is allowed to go into the dip tubs after leaving the flat coolers, and some of it is directly pumped through a 2" line to the jackets around the gas compressors. The trough, on the gravel roof, through which the heated water runs, is metal lined, and extends the full length of the storage rooms, 240 feet, the water being kept in constant agitation by means of baffles.

The cooling tower consists of a number of shelves made of one inch boards, placed .375" apart, the boards on alternate shelves running at right angles to each other. Water falling on the top shelf, drips through the cracks, and over the sides to the shelves below, falling into the reservoir at the bottom, cooled and ready for use again. The water leaves the tower at about 80 degrees Fahrenheit. The cooling tower is 32 feet high, and slopes from a width of 6 feet at the top to 32.5 feet at the bottom, making a slope of between 60 and 70 degrees. The reservoir underneath the tower is 45 feet wide and 12 feet high.

## COAL.

Illinois screenings is the coal used in this station. An average of 28.5 tons are consumed per day. The coal is shipped to the plant via the Chicago,

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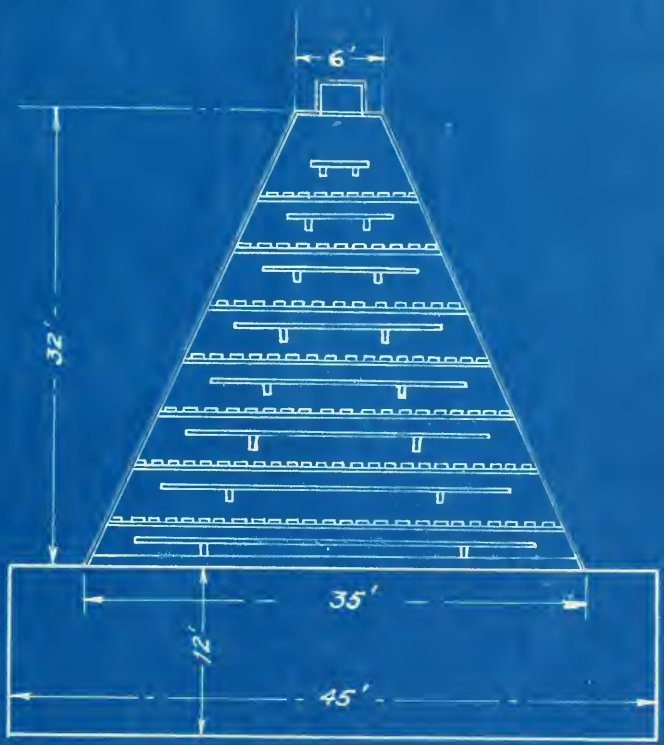


COOLING TOWER
ARRANGEMENT

FIG. 9.

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Milwaukee, & St. Paul Railroad, and is switched into the yards, at the northern end of the station. Laborers shovel the coal through a 2' chute, which carries it to a 30' coal elevator of the C. O. Bartlett & Snow Co. make. A 220 volt, 3 phase, 60 cycle, 5 horse-power Fairbanks-Morse induction motor operates the elevator, which passes over a large sprocket, the teeth of which engage with the links of a chain on the back of the coal buckets. The induction motor is back-geared, the gear ratio being 8:1. The large gear is on the same shaft as a smalllpulley to which a larger pulley,operating the elevator, is belted. The buckets on the elevator dump the coal into the chain drag, which carries the coal to the bunkers. A small ⅛" pipe delivers water through 6 .0625" holes on to the coal as it enters the bunkers, giving it the proper percentage of moisture. The coal can be made to fall in any of the four bunkers, by opening the chain above that respective one. The coal bunkers are 10'x10'x12' and allowing 45 cubic feet of coal to the ton, each bunker has a capacity of 26.6 tons making a total capacity of 106.4 tons. The chain conveyor is also driven by a 3 phase 5 horse-power back-geared, Fairbanks-Morse induction motor. Each boiler when running at full load consumes about 6 tons of coal per 8 hours.

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## HANDLING OF ASH.

A very peculiar method was devised by Olson Brothers & Co, Chicago, for taking care of the ashes. The ashes drop into pits directly underneath the boilers, each pit being provided with a 6 inch pipe through which the ash is conveyed to an elevated ash bin, by means of a #7 Sturtevant exhaust fan operating at 2675 revolutions per minute and which can create a suction of 10 ounzes at intake, and has a capacity to deliver 2180 cubic feet of air per minute, consuming ten horse-power. Upon entering the bin, the ashes are sprayed with water which settles the dust, and allows them to fall to the bottom of the bin. The air passing around the baffle plate is drawn to the exhaust fan, and out to the atmosphere, the fan being direct-connected to a 3 phase 40 Kilowatt, back-geared, Fairbanks-Morse induction motor. The bin is 8 feet in diameter by 8 feet deep, with a 45 degree slope at the bottom. By operating a slide at the bottom of the bin, the ashes fall into a wagon to be carried away. When a boiler is running at full load, 1300 pounds of ash are given off every 8 hours. The accompanying sketch shows the construction of the Ash Handling system. This tower is located about 20 feet from the northern extremity of the station.

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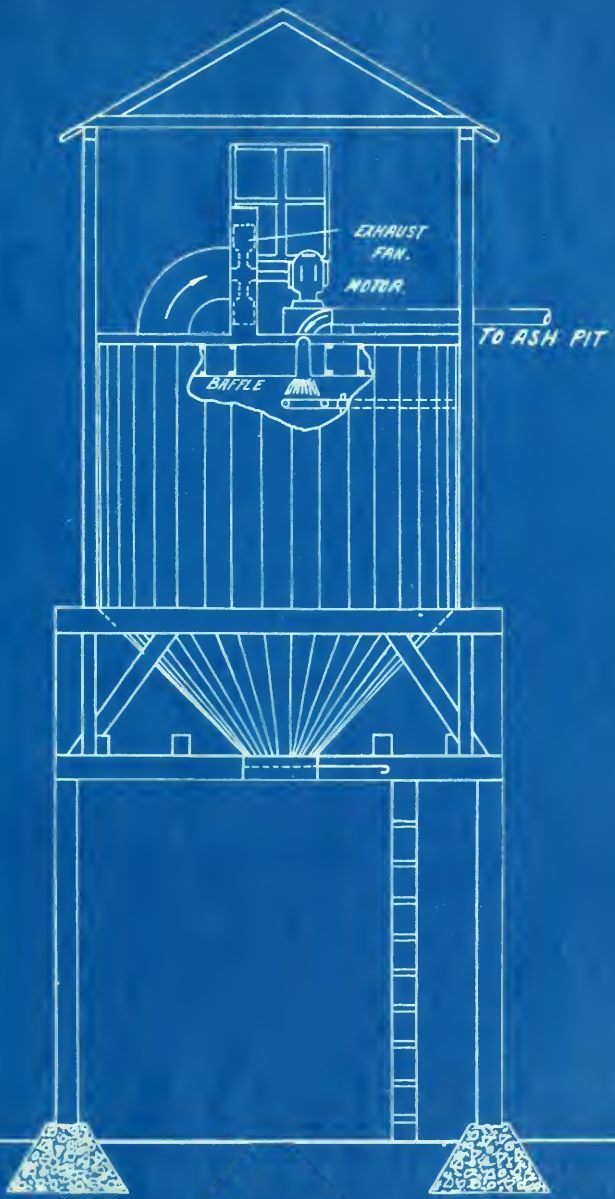


DEVICE FOR HANDLING ASH FROM THE BOILERS

FIG. 10.

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THE ELECTRICAL EQUIPMENT OF THE STATION.

The main generating unit is a Crocker-Wheeler, 75 K. W. 3 phase, 240 volt, alternator running at 277 R. P. M. and furnishing current at 60 cycles. The machine has a star wound armature, and a rotating field of 26 poles. The alternator is direct-connected to a 12" x 15" Skinner engine. The exciter is on the same shaft, and delivers current at 125 volts. This exciter is a compound direct current generator, and rheostats are provided on the switchboard, for raising and lowering the voltage both in the shunt and series fields. The exciter has a capacity of 3.8 Kilowatts, and its full load current is 30.4 amperes. This large alternator furnishes all the power for the entire station, there 12-3 phase induction motors, incandescent lamps and arc lights. The motors range from 1 to 40 horse-power and operate at 220 volts. The lights of the station are all connected between phase and neutral, as 125 volt lamps are used. An auxiliary engine and generator are installed which consist of an "Ideal" engine made by A. L. Ide & Sons Co., 11" - 14", of the piston valve type, running at 275 R. P. M. and belted to a 6 pole, 240 volt, 60 cycle, 3 phase, 60 Kilowatt Bullock Generator. The exciter for this alternator is a series machine and is direct-connected, delivering current at

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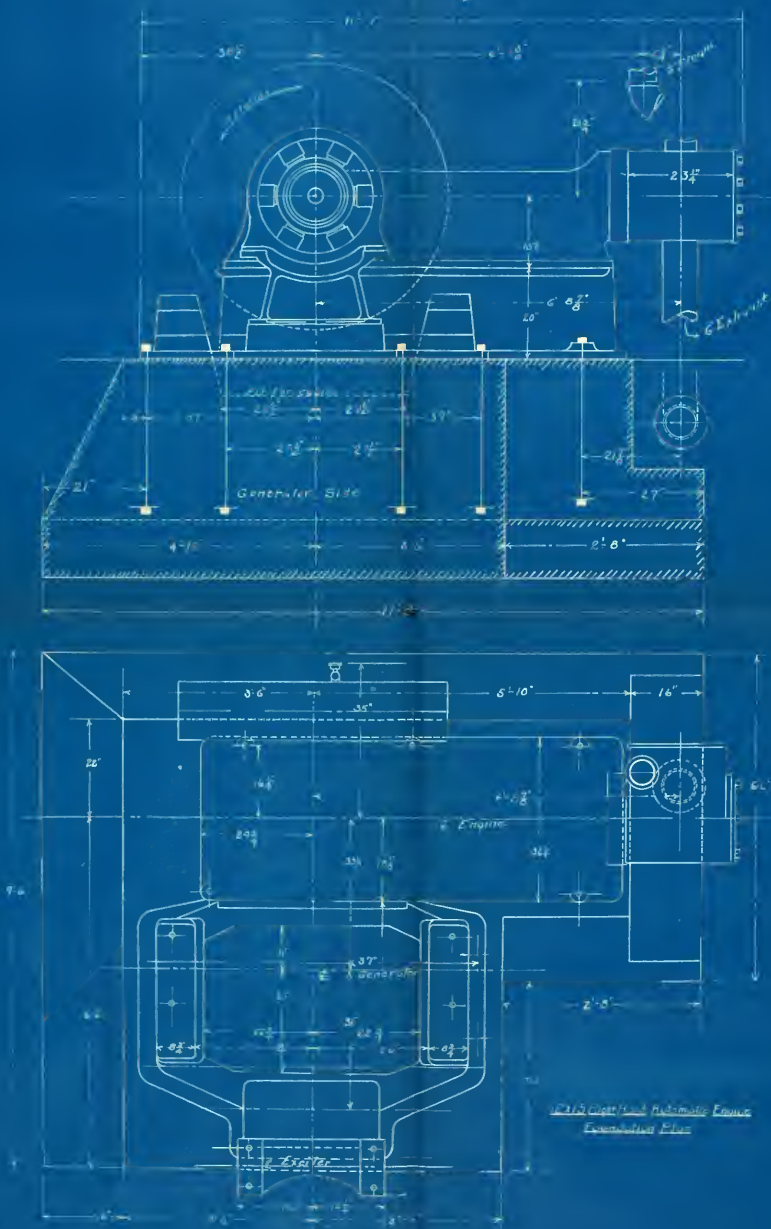


12 x 15 Flight Hood Automatic Engine
Foundation Plan

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120 volts. Full load current for this exciter is 20 amperes. Both the alternator and the exciter have a normal speed of 1200 R. P. M. The resistance of the armature winding is .0296 ohms, while that of the field winding is 4.74 ohms.

Synchronizing apparatus has been installed but on account of the difficulty in keeping up the voltage of the smaller machine, they are never run in parallel. The larger unit is used about 22 hours per day on the average, the other being used only to furnish current, in case the larger machine is shut down for repairs or re-oiling. Governors are placed upon the fly-wheels of the engines, keeping the current generated at 60 cycles at all times. The leads from the main generator to the switch-board are run underneath the main floor, all the cables being doubly insulated. The conduit contains 4 leads from the generator, 3 from the extremities of the phases, and one from the neutral, and 5 field wires, 3 from the 8-pole Type C.C.D. Crocker-Wheeler direct-current exciter, and 2 returning to the collecting rings of the alternator.
The Skinner system of lubrication usual with Skinner engines, is used on this unit, it consisting of a rod

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connected to a pawl, and the eccentric rod. The pawl actuates a ratchet, which in turn causes a cam to rotate, operating a valve which allows oil to flow at regular intervals.

Wiring throughout the plant is in iron conduits, and as alternating current is used throughout the system, there is little danger of electric sparks setting fire to the ammonia gas.

THE SWITCHBOARD.

The board consists of 2 panels, 40" x 60", equipped with Wagner Electric Company's instruments. The accompanying wiring diagram of the two units, and the switchboard, shows the connections of the machines to the board as well as all instrument connections. Two 400 ampere A. C. Ammeters, #10268 and #10270, Type R, one 300 volt, Voltmeter, #9567, Type R, two 125 K. W. Wattmeters reading correctly at 60 cycles, #10033 and #10036, Type F, and one Westinghouse single phase synchroscope, #99715, are placed on the two panels. Two rheostats for the regulation of voltage, are placed upon each panel. A switch for determining the voltage between phases on either machine or any phase to neutral, may be found on the board. A table is found in the accompanying wiring diagram, showing relative voltages as actually tested

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# REGISTER OF POWER APPARATUS

| MAKER | HP | E | R.P.M | Current/phase | Serial number | Use | Location | Location of Maker |
|---|---|---|---|---|---|---|---|---|
| FAIRBANKS-MORSE | 10 | 220 | 900 | 100 | 11939 | DRIVE PUMP | ENGINE ROOM | INDIANAPOLIS, IND. |
| WESTINGHOUSE | 15 | 200 | 1120 | 42.1 | 619170 | AIR COMPRESSOR | ENGINE ROOM | PITTSBURG, PENN. |
| WESTINGHOUSE | 1 | 200 | 1700 | 5.5 | 379361 | DRIVE PUMP | MEZZANINE FLOOR | PITTSBURG, PENN |
| WESTINGHOUSE | 5 | 200 | 1120 | 148 | 26588 | CIRCULATING PUMP | STORAGE ROOM | PITTSBURG, PENN. |
| GENERAL ELEC. CO. | 5 | 220 | 1200 | 12 | 15 SA 1200 | CIRCULATING PUMP | STORAGE ROOM | SCHENECTADY, NY |
| WESTINGHOUSE | 3 | 200 | 1120 | 11.5 | 521683 | BRINE CIRCULATOR | TANK ROOM | PITTSBURG, PENN. |
| WESTINGHOUSE | 3 | 200 | 1120 | 11.5 | 521680 | BRINE CIRCULATOR | TANK ROOM | PITTSBURG, PENN. |
| WESTINGHOUSE | 3 | 200 | 1120 | 11.5 | 521684 | BRINE CIRCULATOR | TANK ROOM | PITTSBURG, PENN. |
| WESTINGHOUSE | 3 | 200 | 1120 | 11.5 | 521681 | BRINE CIRCULATOR | TANK ROOM | PITTSBURG, PENN. |
| FAIRBANKS-MORSE | 5 | 220 | 1200 | 13 | 14162 | COAL CONVEYOR | BOILER-ROOM ABOVE BUNKERS | INDIANAPOLIS, IND. |
| FAIRBANKS-MORSE | 5 | 220 | 1200 | 14 | 13042 | COAL ELEVATOR | BOILER-ROOM ABOVE BUNKERS | INDIANAPOLIS, IND. |
| FAIRBANKS-MORSE | 30 | 220 | 1200 | 76 | 12494 | ASH CONVEYOR | ASH TOWER | INDIANAPOLIS, IND. |

DATA SHEET NO. 1

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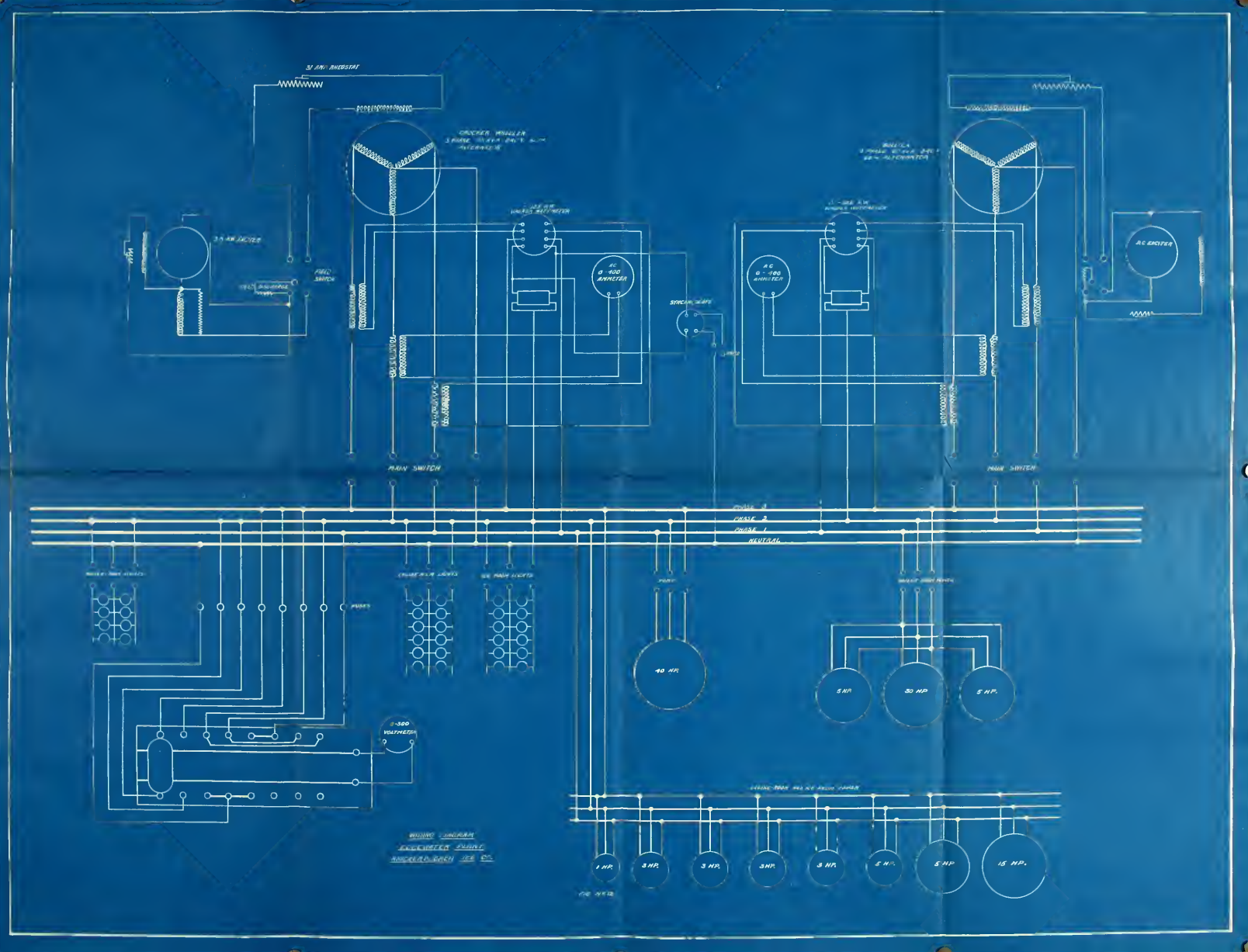
MAIN SWITCH
MAIN SWITCH
PHASE 3
PHASE 2
PHASE 1
NEUTRAL
40 HP.
5 HP.
30 HP.
5 HP.
1 HP.
3 HP.
3 HP.
3 HP.
3 HP.
5 HP.
15 HP.

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out, and also a scheme of the switch's connections. In places where the voltage ought to have been zero the voltmeter gave an indication of 50 volts, showing a ground on the system. Later experiments with induction motors, showed the ground to be in the conduit leading to the brine circulators.

The bus bars on the rear of the board are ¼" x 1.75" copper bars. Two potential and 6 series instrument transformers, are to be found on the back of the board. Field discharge resistances have been included in the equipment, but on account of incorrect installation, they have been of no use in reducing the large arcs at the field switches. Junction boxes are placed in the engine room, boiler room and freezing room, where fuses may be replaced. We tapped in at the junction boxes in our induction motor tests.

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## THE BOILER ROOM.

This room, the dimensions of which are 48 x 46 x 42, contains the steam generating system - a battery of 4 Erie City Iron Works return tubular, 200 Horse-power boilers, 72" x 20', each equipped with a Green chain grate, having a live surface of approximately 5 x 8 feet. These grates are driven by eccentric rods from a shaft belted to a 4"x 8" Wachs vertical engine. Coal can be fed into the fire rapidly, or very slowly, by regulating a pawl, which engages with a ratchet to move the grate. The height of the fire can also be regulated by a worm which lowers or raises a vertical plate,fixing the height of the coal as the grate moves along. The boilers have 4" tubes, and have an average effiency of about 62%.

The water fed into the boilers is taken from the city main, a 4 inch pipe leading into the boiler room from Evanston Avenue, through a large water meter. The water is piped directly to the Kennicott Water Softener, where it is treated. From the Softener, the water is again brought into the boiler room, to a 3' 9" diameter Baragwanath open feed water heater, which is 10.5 feet long, and heats the water up to about 200 degrees. The feed water heater was originally installed on the second floor near the steam condensers. However,

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# FEED WATER PIPING

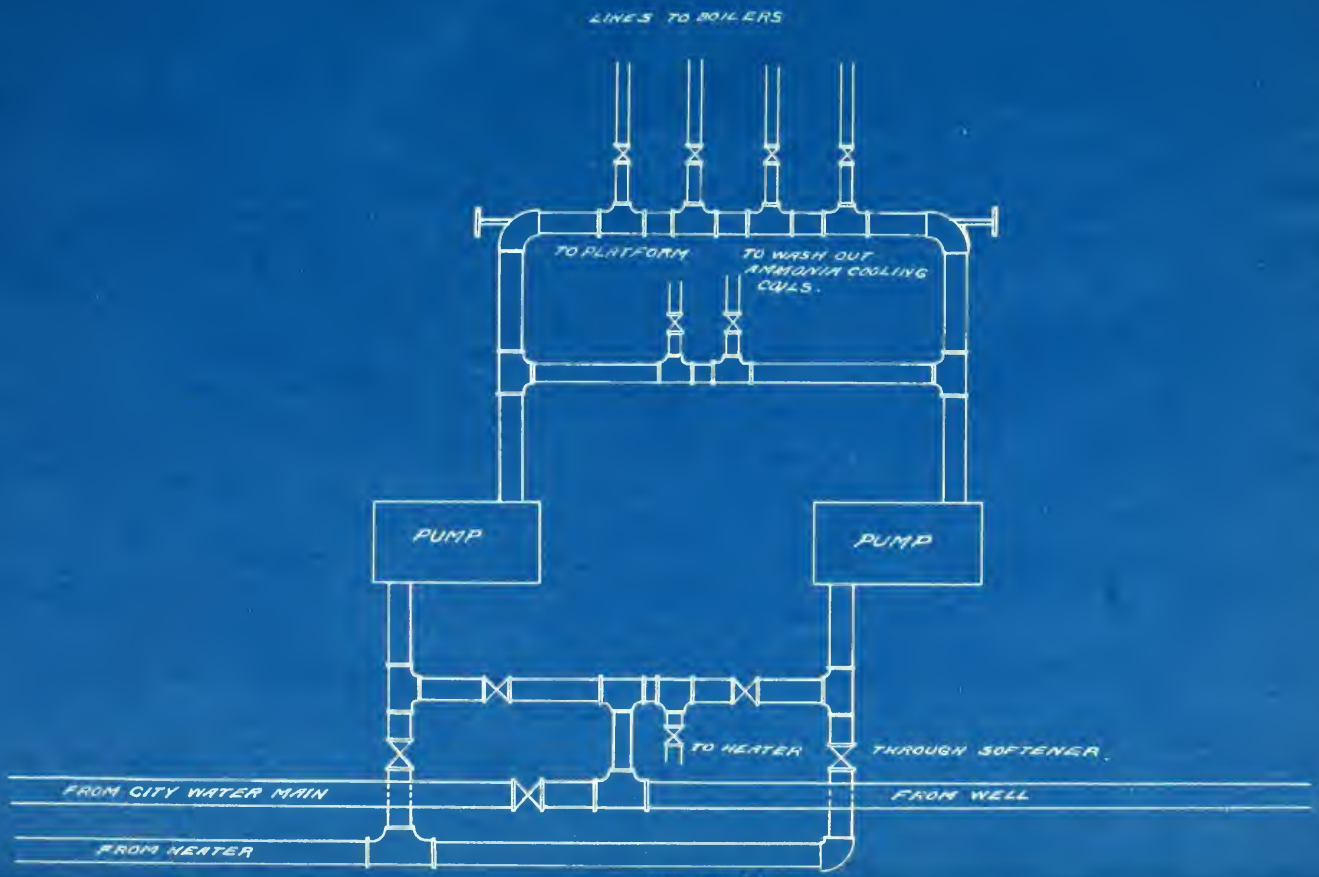


FIG. No. "A"

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cooling water was then used to help feed the boilers, but this scheme has now been abandoned. The feed-water heater is now located in the southern portion of the boiler room, near the feed water pumps. The amount of water entering into the open heater is regulated by a float valve, which adjusts itself for a constant flow. The heater is directly connected to the suction of the two cross-connected boiler feed pumps of the Marsh type, each 10"x6"x12", made by the American Pump Company of Battle Creek Michigan.

The four boilers generate steam at an average pressure of 120#. All the boilers are supplied with large 4 foot Crane live steam separators of the vertical type, insuring dry steam at all times. The dryness of the steam direct from the boilers, before it entered any separators was found to be 97.75%. Each boiler is connected to the main steam line running in an easterly and westerly direction, across the boiler room, by a separate 7" main. The large 240 Horse-power Corliss engine in the engine room, has steam delivered to its cylinder through a separate 10" header, while all the pumps, engines and other apparatus are fed by a 6" header. The boilers are

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all equipped with a 4½" pop valve and have a 4" blow-off connection with a 2½" blow-off cock. Each boiler is fed through the blow-off with a 1½" feed connection. The breeching, connecting the boilers to the stack is round, and made of ¼" sheet iron, 5' 8" at the small end and 6' 4" at the large end. At the large end the breeching changes section to 4' x 8', where it enters the stack. The stack is made of brick lined with fire brick, is 5'6" in diameter, and 125 feet high. The average temperature of the leaving gases in the breeching was found to be about 575 degrees Fahrenheit. The average draft in the breeching was found to be about .45" of water. The boiler room is ventilated by means of 4-2' circular ventilators in the roof. The roof is reinforced by 18" I beams.

Adjoining the boiler room, are the locker rooms and the shop. Almost all of the pipe fitting and minor repairs for the station are done here, by some of the skilled workmen at the plant.

The ENGINE ROOM.

Every precaution has been taken by the designers of this station to eliminate all the possibilities of an entire shut-down. As the plant is operated every hour of the year, nearly every piece of machinery

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PLAN OF BOILER ROOM

FIG. No. 13

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# 42" x 10'
# HORIZONTAL OPEN HEATER

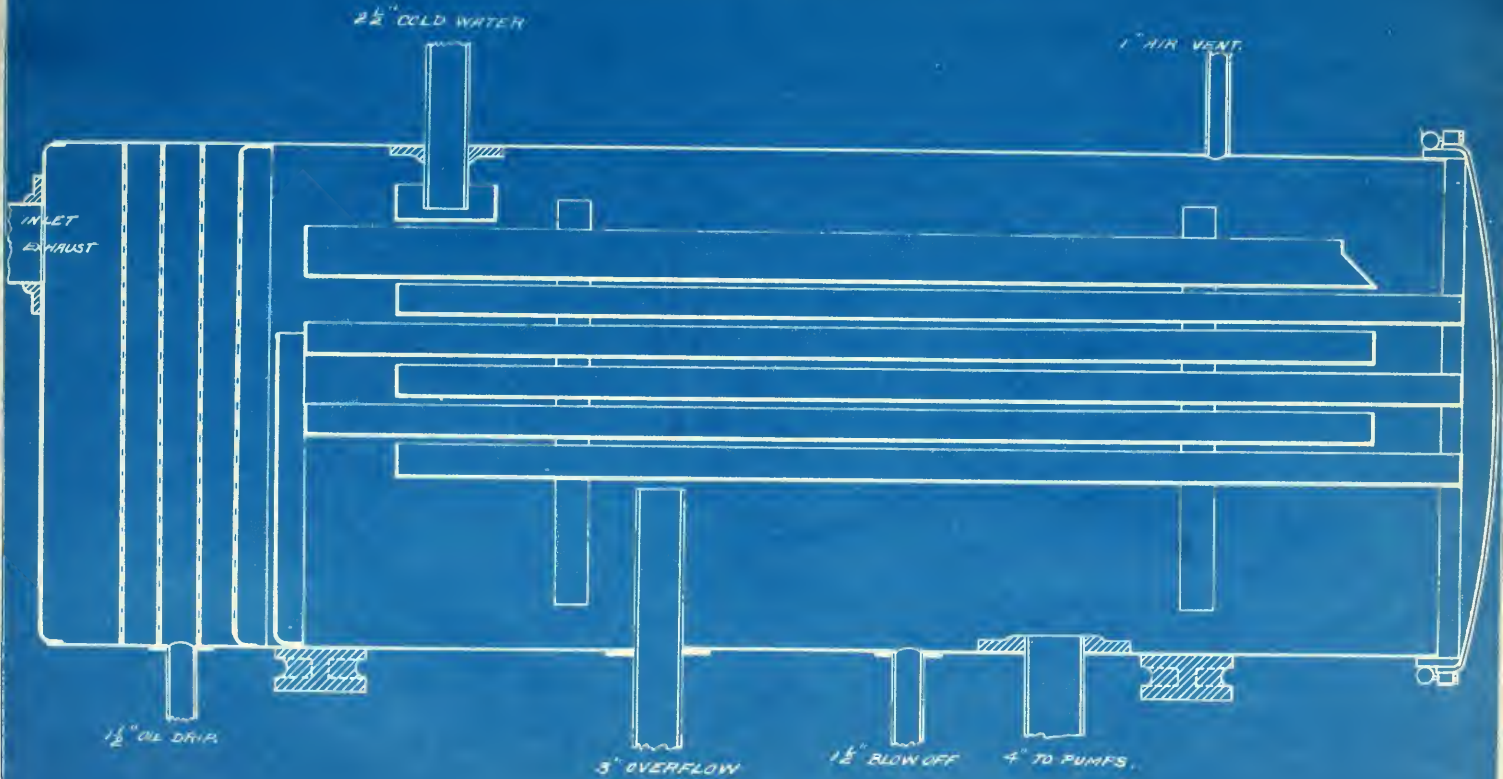


FIG. No 14.

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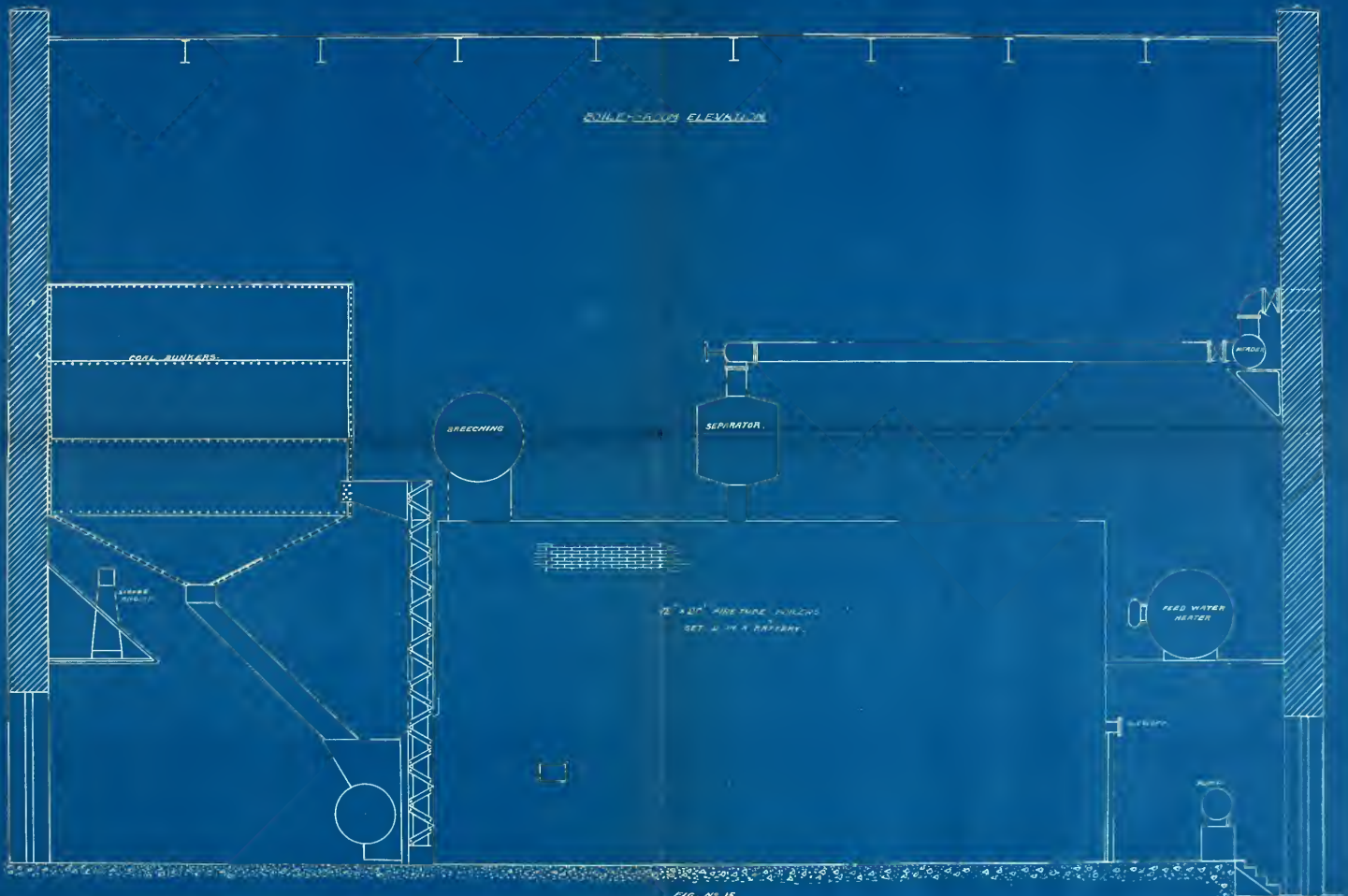
BOILER-ROOM ELEVATION
COAL BUNKERS.
BREECHING
SEPARATOR.
FEED WATER HEATER

FIG. N° 15

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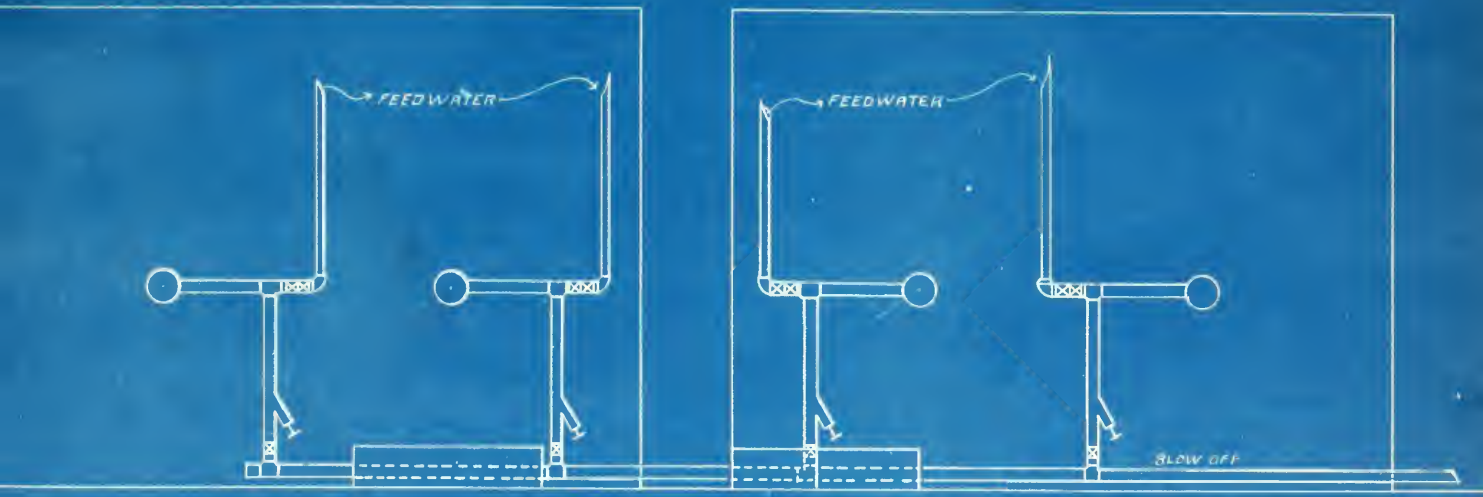


BOILER ROOM ELEVATION

FIG. Nº 16.

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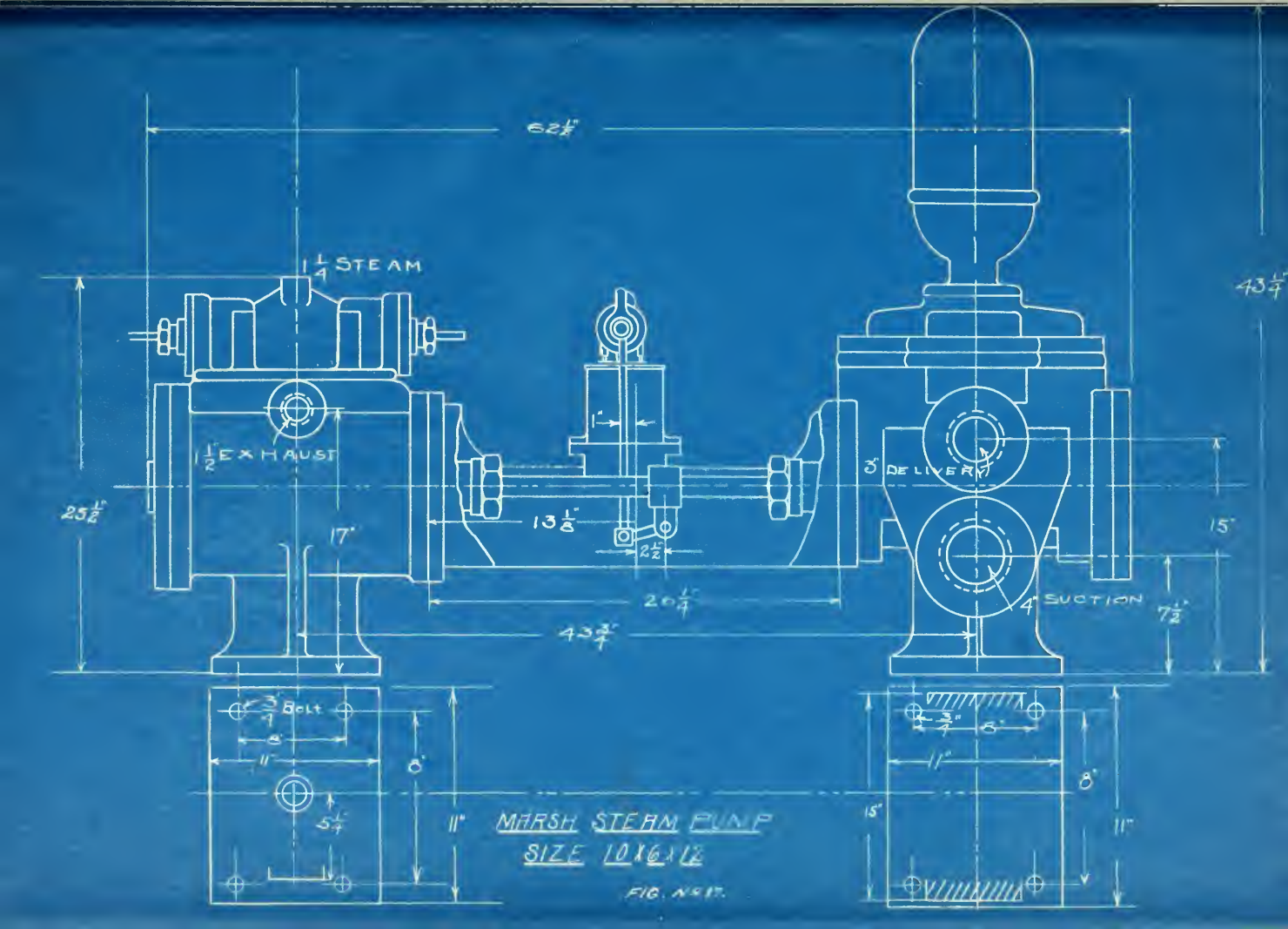
62½"
1¼ STEAM
1½ EXHAUST
25½"
17"
13⅛"
1"
2½"
20¼"
43¾"
3" DELIVERY
4" SUCTION
15"
7½"
43¼"
¾ Bolt
8"
11"
6"
5¼"
11"
MARSH STEAM PUMP
SIZE 10 X 6 X 12
FIG. No 17.
¾"
8"
11"
6"
15"
11"

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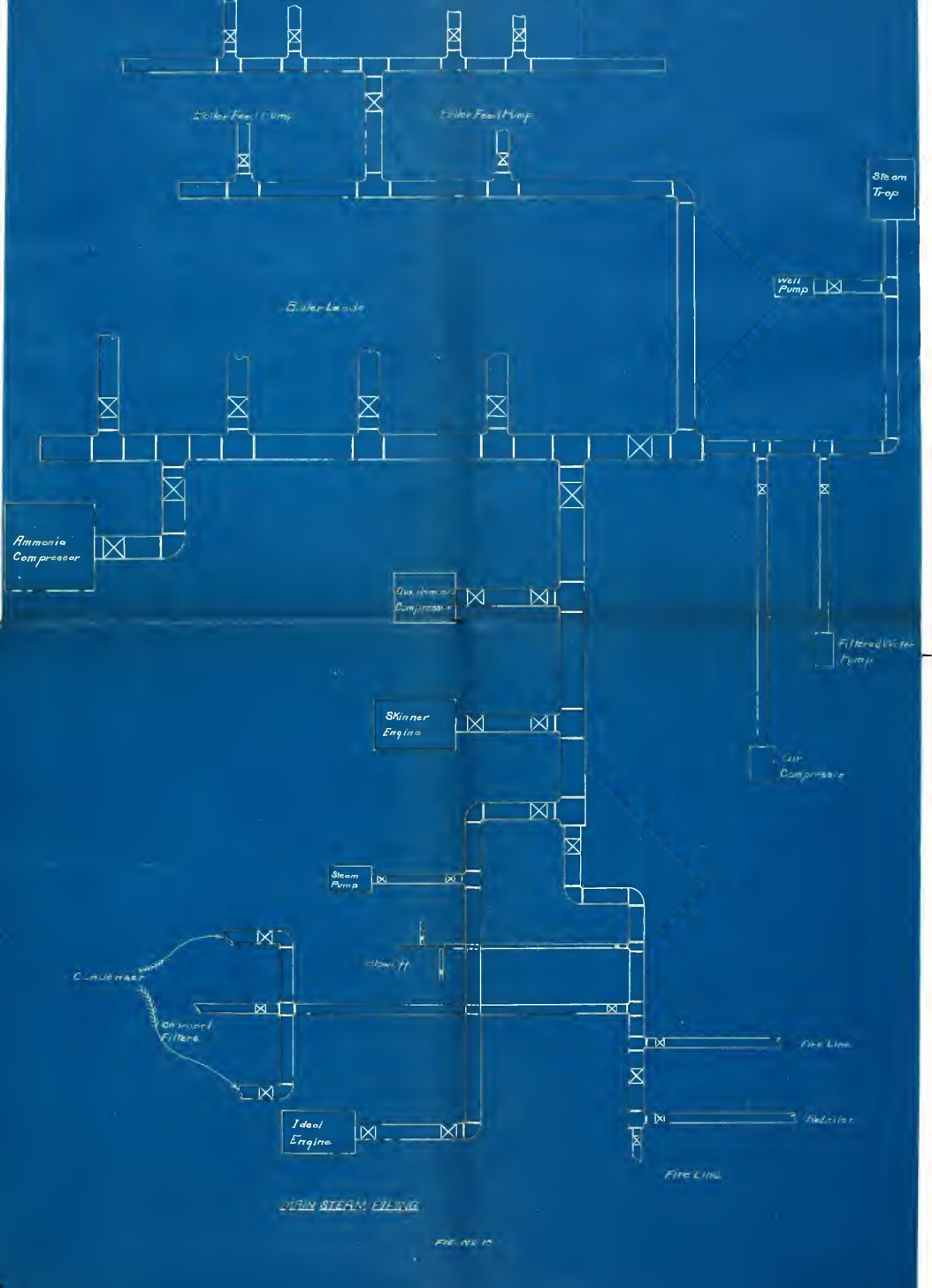


MAIN STEAM PIPING

FIG. NO. 12.

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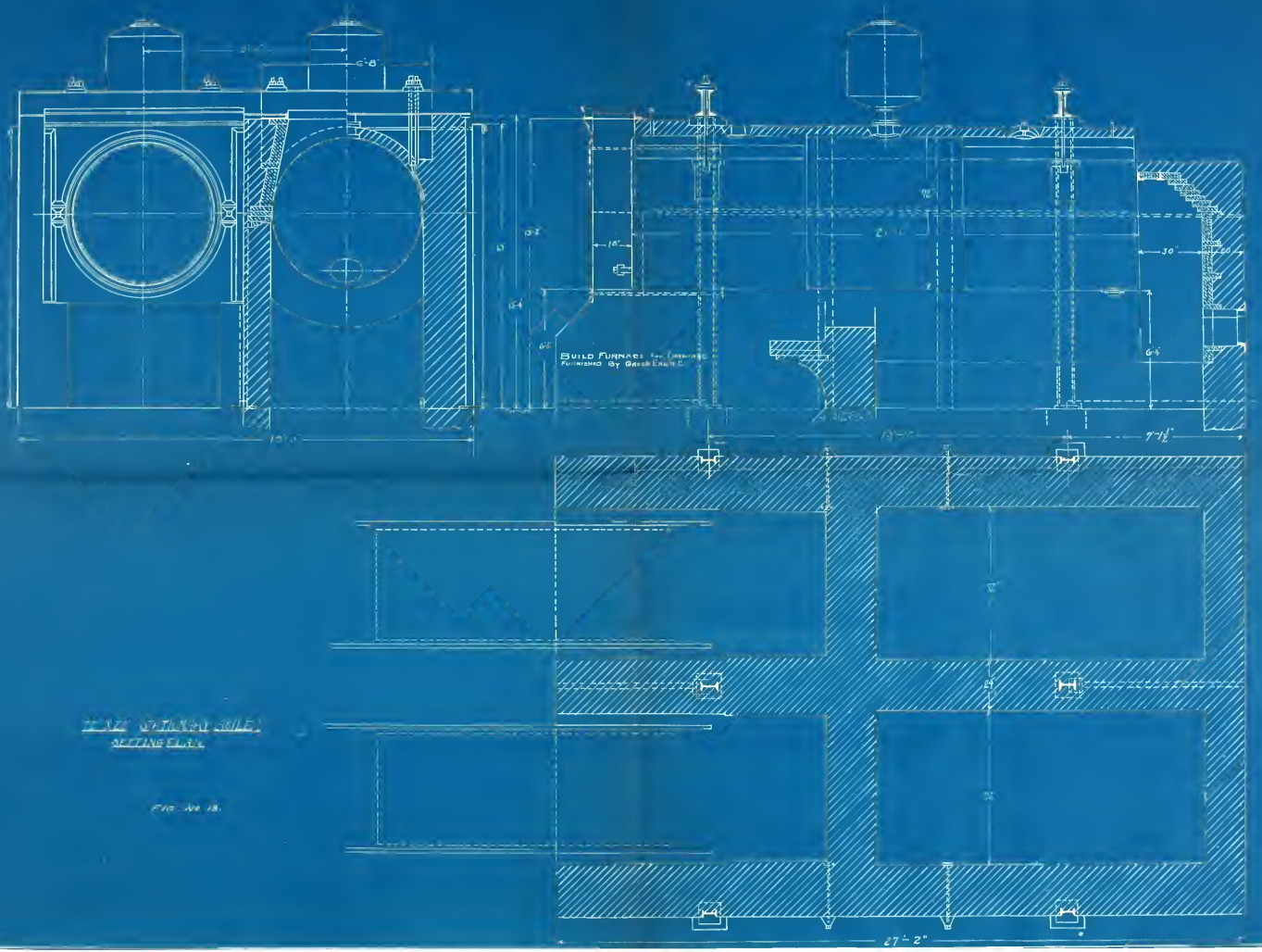
BUILD FURNACE
FURNISHED BY
27'-2"

employed in the engine room has an auxiliary, which is capable of carrying on a large share of the work, and which can be relied upon in case the main machine is shut down for repairs. The contents of the engine room are as follows, as taken from the original specifications and proposal of the York Manufacturing Company to the Knickerbocker Ice Company:--

One improved York Steam engine of the horizontal type, with a cylinder of 36" bore, running at 49.4 R. P. M. and operating a 125 ton ice machine. The cylinder is lagged, and packed with mineral wool. The governor and valve gear are of the Corliss type. A steam stop valve, and a sight feed cylinder lubricator are provided with this engine. This machine drives two ammonia gas compression pumps, of the York improved vertical single acting type, of 24 inches bore, 36" stroke, fitted with cooling jackets and properly lagged. The pumps are fitted with special ammonia stop valves; with the latest improved stuffing boxes, and with a hand pump provided for lubricating pump cylinder and stuffing boxes. Special by-pass valves, and pipes on machine between pumps are provided, enabling charge of ammonia to be drawn from one part of the pipe system and stored in another part. The main shaft, of best forged and hammered steel is 16 inches in diameter, on

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which there is a 16 ton fly-wheel, with a 8 foot radius. The pump frames are of the York standard upright style, the connecting rods and piston rods being of the best steel. The two gas compressors are driven directly from the main engine shaft. All the wearing and bearing surfaces, such as the sliding portions for the cross-heads are fitted with automatic oilers. The pistons are all fitted with metallic packing. On the compressor frame are placed two ammonia gauges and one steam gauge, one ammonia gauge reading the pressure on the high pressure side of the system while the other records the low. The compressor is provided with a set of wrenches and small tools for taking the machine apart for examination or to make adjustments of any part of engine and pumps. A $4\frac{1}{2}$' x $4\frac{1}{2}$' tool board is arranged to receive all of the above tools. One glass test jar, one hydrometer for testing ammonia and one chemical hand thermometer, and one salt gauge for testing the density of the brine, ( chlorides of calcium - Density 80% - Salt scale ) is supplied with the compressor. This machine is guaranteed by the York Manufacturing Company to give a duty equal to the making of 125 tons of ice in 24 hours.

The smaller compressor is a duplicate of the large machine, as far as operation is concerned, being a 16" x 16" Corliss engine attached to two ammonia pumps of

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the vertical single acting type of 11 inches bore and 15 inches stroke. The main shaft is of hammered steel, 7.5" in diameter, carrying a $2\frac{1}{2}$ ton 5 foot fly-wheel.

The ammonia condensers are found in the southern end of the engine room, and consist of the York double tube pipes, there being 28 coils of 1.25" and 2" ammonia pipe. Each coil is 12 pipes high and 19 feet long, needed valves, headers, and water distributing devices being provided. The condenser is furnished with rewash headers. Two 28" diameter, 6.5' horizontal ammonia receivers are placed next to the ammonia condensers, in which the ammonia is kept at a very high pressure. The ammonia connections with the compressors, are so arranged that the machines can be operated together or entirely independant of each other. The ammonia condenser is guaranteed to have a refrigerating capacity of 350 tons with water at 60 degrees Fahrenheit.

In the engine room, there may also be found the two alternating current generators, which supply current to the entire plant. A 75 K. W. 3 phase, star-connected, rotating field, 26 pole, 240 volt, 60 cycle alternator, running at 277 R. P. M. is direct-connected to a 12" x 15" Skinner engine by means of a 5" steel shaft, to which a 3.8 K. W., 30.4 ampere, 8 pole direct-current exciter is also connected. The alternator was made by the Crocker-Wheeler Company of Ampere, New Jersey, and has a full load capacity of 180 amperes per terminal.

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load capacity of 180 amperes per terminal.

The other generating unit, which is used only when the larger machine is shut down, is a 60 K. W. 3 phase, star-connected, rotating field, 6 pole, 240 volt, 60 cycle, alternator, which is belted to a 60 K. W. 11 x 14" reciprocating engine. The diameter of the pulley on the alternator is 15", and that of the pulley on the engine shaft 48". On the same shaft a 5 foot fly-wheel, with a governor attached is connected. The distance between shafts is 22' 8". The belt is of tough leather, 8½ inches broad and ¼" thick. The alternator runs at 1200 R.P.M., as does also the direct-connected series exciter, which supplies current to the alternator at 120 volts and has a full load capacity of 20 amperes.

Besides the 11" x 11"x 12" Locomotive type Westinghouse Air Compressor, a 15 Horse-power motor driven pump is located in the engine room, running at 181 R. P. M. and with an ultimate capacity of 50 cubic feet of free air per minute. This pump was made by the Westinghouse Traction Brake Company of Wilmerding Pa. It is connected to a 15 Horse-power, 200 volt, Westinghouse induction motor of the C C L type.

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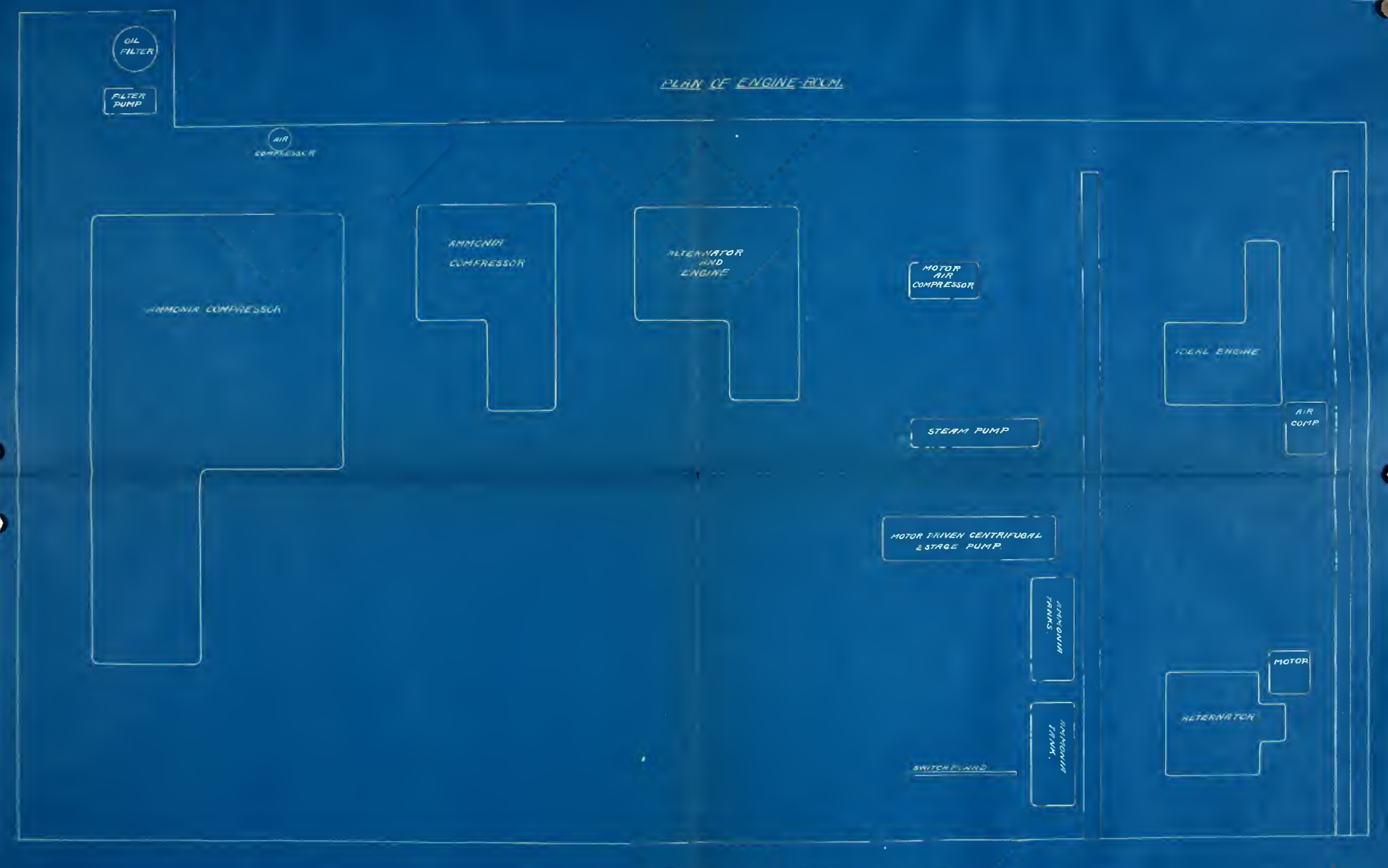
# PLAN OF ENGINE-ROOM.



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The service pumps for distributing the cooling water throughout the plant are located at the southern end of the engine room. A 2 stage centrifugal pump --size 5-- and direct connected to a 40 Horse-power Fairbank's Morse Induction motor is generally used, supplying cooling water to the condensers at about 40# pressure, when the Crocker-Wheeler alternator is used. When the Bullock machine feeds the system, only 30# pressure is kept up, as the unit is considerably smaller. The auxiliary to the two stage pump, is a common 10 x 14 x 20 Marsh pump. The oil skimmer or float trap, mentioned before is also located in the engine room.

On the second floor of the engine room are located the large oil separator in the exhaust steam line, 2 Worthington condensers, 8 charcoal filters, the flat coolers, a sweet water centrifugal pump, directly connected to a 1 Horse-power induction motor and the large sweet water tank. This floor is made of reinforced concrete and is termed the "mezzanine" floor. At night the engine room is illuminated by arc lamps and a few incandescent lamps. Thirty windows each 4' x 4' furnish plenty of light during the day.

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PLAN OF MEZZANINE FLOOR

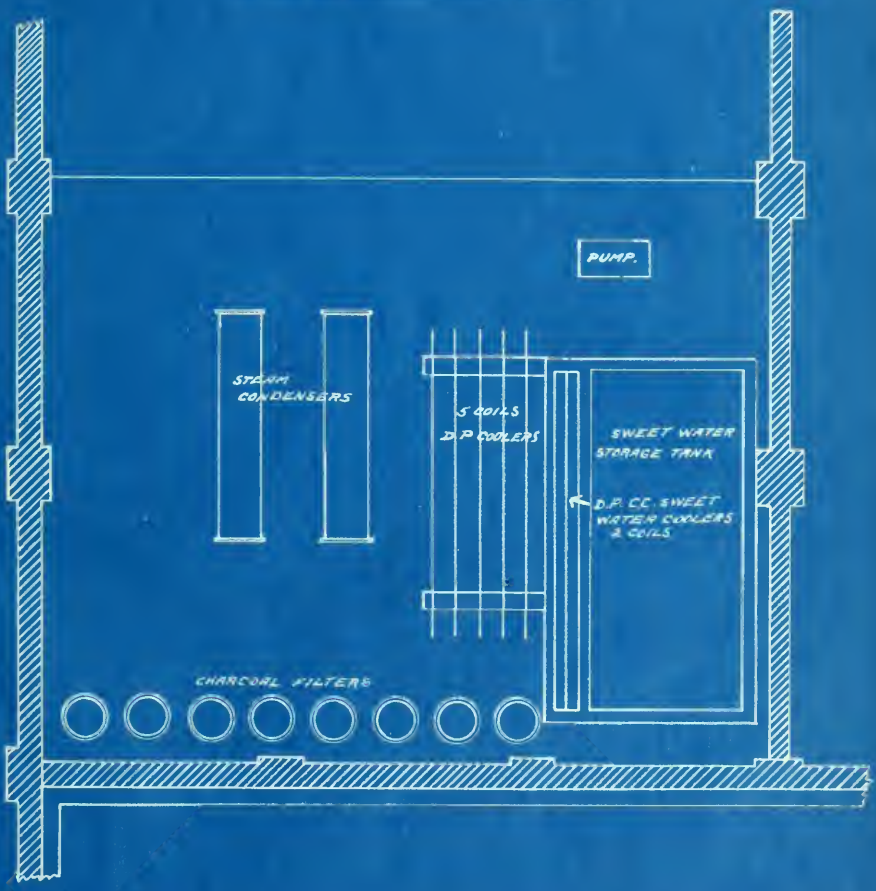


FIG. Nº 20.

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SECTION THROUGH ENGINE ROOM

AT

MEZZANINE FLOOR

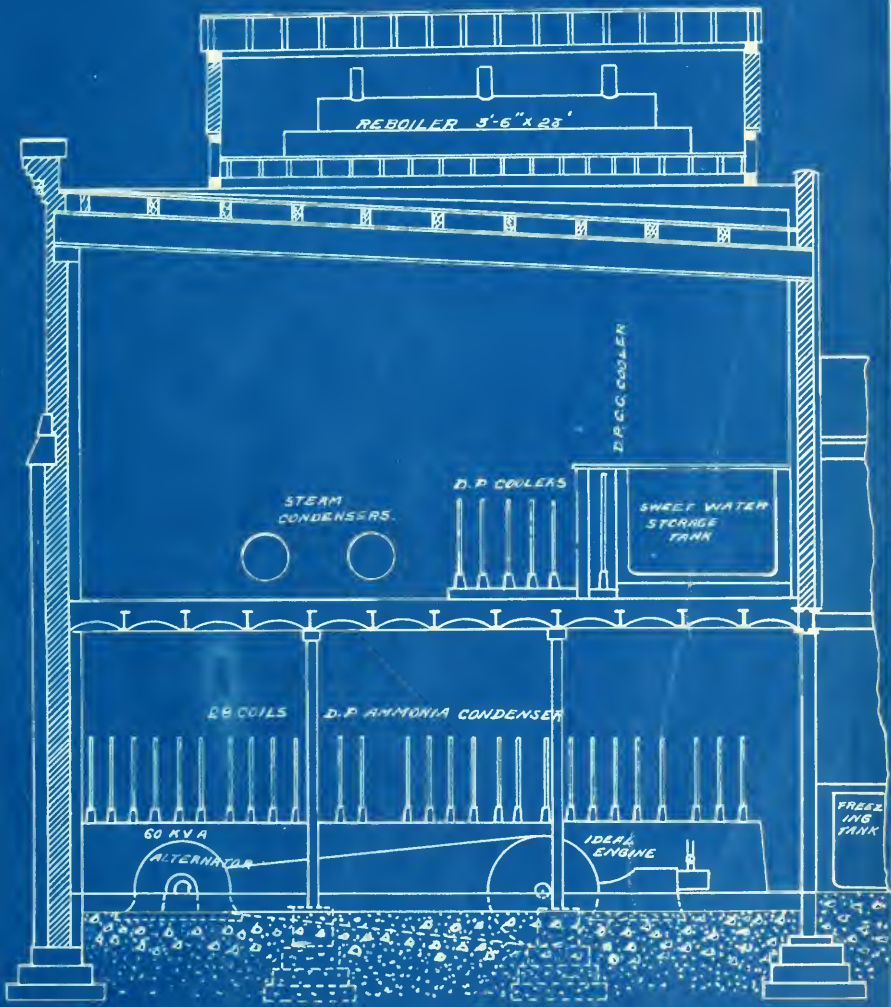


FIG. No. 21.

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SECTION THROUGH ENGINE ROOM

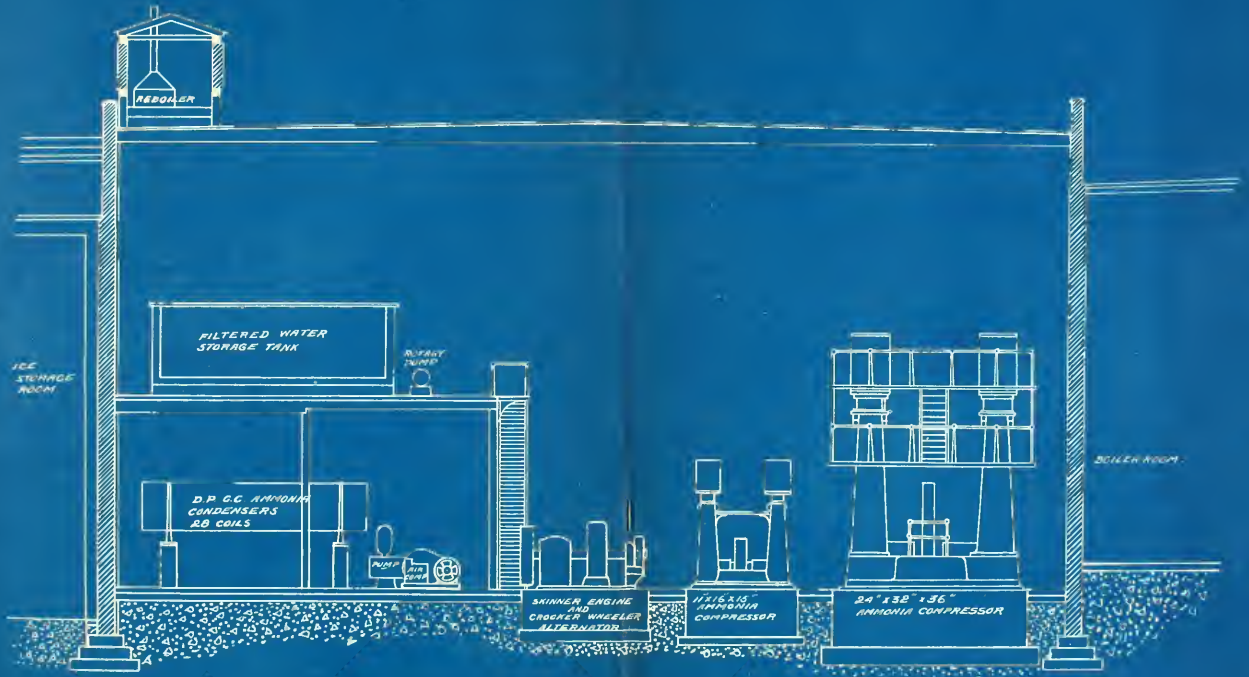


FIG. No 22.

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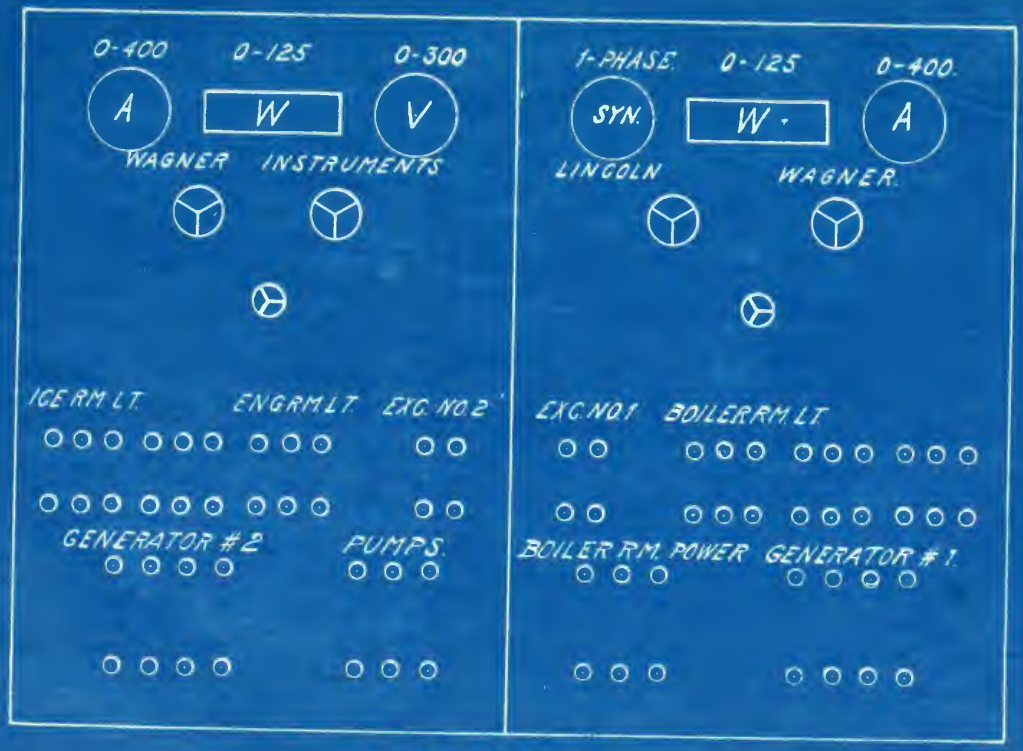


**SWITCHBOARD.**

FIG. 23.

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SWEET GOODS COMPOUNDING ROOM.

In this room may be found the Erb Double Acting pump, drawing water from the deep well, underneath the plant, the water being stored under the Kennicott Water Softener in a large concrete basin. The compounds for softening the water are mixed in this room and fixed charges are pumped into the Softener receptacle at the top of the tower.

"TYPE B" WATER SOFTENER.

The Kennicott Softener is a very simple device for charging water with a certain amount of marble-head lime and sal soda in order to soften the water, and make it fit to be run through the plant's system. The water softener is a tower, some thirty feet high, to which the city water is delivered before it goes to the boiler feed pumps. The apparatus itself, consists of two basins, which resemble two axial cuts from a large cylinder, and which from an end view look like two quadrants of a circle. The basins revolve on an axle at the junction of the three sides, and they are so arranged that water can only flow into one at a time. As the water comes to a certain level in one basin it brings the centre of gravity of the cans over so far, as to cause them to tip, and allow the water to flow from the filled one. At the same

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time, two small cups are brought out of the vessel containing the "charge", filled with lime and soda and they are dumped into the outflowing water. In this manner, every time enough water comes into the "quadrant" can to tip it, which of course is a definite weight, two small cupsful of the charge are mixed with it. Thus the water is treated uniformaily and any deviation in the causticity, hardness or alkalinity of the treated water, readily shows up in the chief engineer's tests, should any occur. The charges are 10 pounds of marble-head lime and 7 pounds of sal soda. These charges are siphoned up to the tower three times daily. About 35000 gallons, or 146 tons, of water passes through this softener per 24 hours.

KENNICOTT METHOD FOR CHARGING AND TESTING.

Hardness:-

Measure out 100 cc. of the treated water, pour it into a bottle, and run in a standard soap solution from a burette. Run in only .5 to 1 cc. at a time and shake the bottle well after each addition of soap solution. As soon as a permanent lather is formed, enough soap solution has been used. The number of cc. used is called the hardness.

Alkalinity and Causticity:-

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Measure out 100 cc. of the treated water and pour it into the color bottle, add 2 drops of the red indicator, also a few drops of the clear indicator, and run in, from a burette, a standard acid solution, until the red color becomes orange. The number of cc. used is called the causticity. Run in more of the standard acid until the orange color changes to pink. The total number of cc. used is called the alkalinity,( both color changes being included).

Treated water should show tests as follows:

| | | |
|---|---|---|
| Hardness | not to exceed | 9 |
| Causticity | not to exceed | 12.5 |

In case these limits are exceeded, correct the treatment by changing the charges, until tests improve, according to the following table:

1. If causticity is more than .66 of the alkalinity, or greater than 12, decrease the lime charge 5#.
2. If causticity is less than .66 of the alkalinity, or less than 7, increase the lime charge 5#.
3. If alkalinity is less than the hardness, increase the soda charge, (natural soda water).
4. If alkalinity is more than 4 points above the hardness, decrease the soda charge.

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## CONTENTS OF THE KENNICOTT CABINET.

3 500 cc. aspirator bottles, (on top shelf).
2 50 cc. Mohr's burettes, (mounted on door).
1 16 oz. French square bottle.
1 8 oz. Bottle.
2 1 oz. Wide-mouth bottles.
2 2 oz. Dropping bottles.
1 100 cc. Graduated Cylinder.
5 Medium Pinch Cocks.
3.5 ft. Pure Gum Tubing -
0.25" inside diameter by .0625" thick.
Standard Soap Solution.
Standard Acid (Fiftieth Normal - $H_2SO_4$.)

## LUBRICATOR CAPACITY.

| | | |
|---|---|---|
| 125 Ton Ice Machine - #1 | 4.5 | Quarts. |
| 15 Ton Ice Machine - #2 | 1.0 | " |
| Skinner Engine - #3 | 2.0 | " |
| Ideal Engine | 1.0 | " |
| Service Pump | 1.0 | " |
| Sweet Water Pump. | 1.0 | Pint. |
| Deep Well Pump. | 1.0 | " |
| Boiler Feed Pump (each). | 1.0 | " |
| Stoker Engine | 1.0 | " |

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# ENGINEER'S REPORT.

MARCH 31, 1909.

## PRESSURES.

| Time | R. P. M. | Steam. | Ammonia. High. | Ammonia. Low. |
|---|---|---|---|---|
| 8:00 | 48 | 119 | 130 | 15 |
| 10:00 | 48 | 120 | 120 | 15 |
| 12:00 | 48 | 118 | 120 | 15 |

## TEMPERATURES.

| Steam Condenser | | Storage Tank | D. P. Cooler | Tower. |
|---|---|---|---|---|
| On | Off | In | | Off |
| 82 | 106 | 79 | 64 | 75 |
| 82 | 106 | 82 | 60 | 75 |
| 88 | 108 | 83 | 62 | 74 |

| ICE. | | | POWER. |
|---|---|---|---|
| Ice Tanks. | | Storage Rooms. | K.W. |
| #1 | #2 | #1 | |
| 13 | 13 | 30 | 52 |
| 13 | 13 | 30 | 53 |
| 14 | 14 | 30 | 52 |

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The plant is in operation 24 hours per day, the time being divided into 3 watches of 8 hours apiece, 3 to 11 P.M., 11 to 7 A. M., and 7 to 3 P.M. The total average output of the plant is 125 tons of ice per day, with an average coal consumption of 28.5 tons. This falls a trifle short of the standard ratio, in modern refrigerating plants, of 6 tons of ice to 1 ton of coal. The average cost of running the plant, neglecting all losses after the ice leaves the store rooms, and not taking into account depreciation and repairs, is $86.74 per 24 hours. The cost of producing a ton of ice is therefore approximately 8674 divided by 125, or 69 cents. The following table shows a list of the expenditures taken into account in calculating the cost of producing the ice.

| | |
|---|---|
| Salaries per day | $40.80 |
| Average cost of coal | $38.50 |
| Average cost of oil | $ 1.50 |
| Average cost of water, at 7¢ per 1000 gallons | $ 5.94 |
| | $86.74. |

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EMPLOYEES AND PAY ROLL.

APRIL 22, 1909.

| Name | Address. | Position | Salary. |
|---|---|---|---|
| B. M. Kirker | 522 Winthrop Ave | Chief Engineer | $5.00 |
| W. A. Wolters | 1049 Foster Ave | Engineer | $3.00 |
| Gordon G. Fee | 1068 Carmen Ave | Engineer | $3.00 |
| Gustave Reich | 2320 Sacramento | Engineer | $3.00 |
| Henry Taylor | 1 Avery Court | Oiler | $2.20 |
| R. H. Gregory | 148 Townsend St | Fireman | $2.50 |
| G. M. Wood | 2544 Evanston Ave | Fireman | $2.50 |
| Adam Grundal | 340 W. Harrison | Fireman | $2.50 |
| David Fair | 2886 Ainsley St | Tank Room | $2.20 |
| Stephen Fletcher | 66 Perry St | Tank Room | $2.20 |
| John Growney | 2030 Ravenswood | Tank Room | $2.20 |
| Pop Walters | 620 Thorndale | Tank Room | $2.20 |
| B. Stafen | 2030 Ravenswood | Ice Room | $2.50 |
| Simon Dreck | 2886 Ainsley St | Boiler Cleaner | $2.00 |
| Geo. Growney | 2030 Ravenswood | Ash Handler | $2.00 |
| Paul Dreck | 2030 Ravenswood | Laborer | $2.00 |

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ALTERNATOR TEST.

COMMERCIAL EFFICIENCY TEST OF A 3 PHASE

75 K.W. 240 VOLT CROCKER-WHEELER 60 CYCLE ALTERNATOR.

- - - - - - - - - -

JANUARY 27, 1909.

APPARATUS:-

#3732 A.C. Wattmeter.
3076 A.C. Wattmeter.
433 A. C. Wattmeter.
144085 A.C. Ammeter.
111756 A.C. Ammeter.
115099 A.C. Ammeter.
5246 A.C. Voltmeter.
2098 D.C. Ammeter.
235647 Frequency-meter.
3 Series ( 50 to 1 ) Transformers.
External Spring Thompson Indicator.
6 Pole Double-throw Switch.
Small Switch Board.

OBJECT:-

To determine the efficiency and regulation of the main generating unit in the Knickerbocker Ice Company's Edgewater Plant, under various loads.

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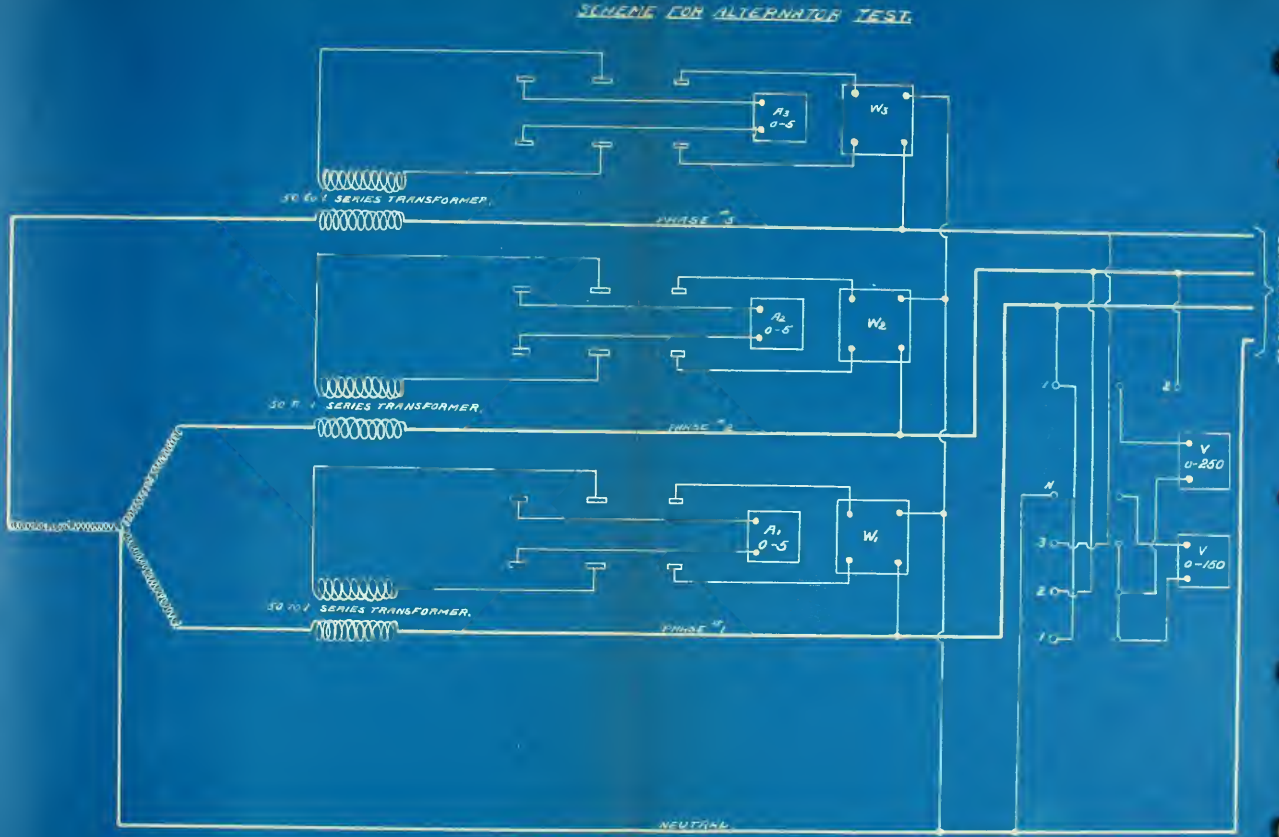
SCHEME FOR ALTERNATOR TEST.
A3 0-5
W3
50 to 1 SERIES TRANSFORMER.
PHASE "3"
A2 0-5
W2
50 to 1 SERIES TRANSFORMER.
PHASE "2"
A1 0-5
W1
50 to 1 SERIES TRANSFORMER.
PHASE "1"
TO SWITCH BOARD.
1
2
N
3
2.0
1.0
V 0-250
V 0-150
NEUTRAL

FIG. No 24.

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According to the standards adopted by the American Institute of Electrical Engineers, the horse-power input, as measured by the indicator cards, when the direct-connected alternator is driven at normal speed with unexcited fields, must be subtracted from all the following input values, in order to give the alternator its full efficiency and not unjustly ascribe any of the friction losses of the steam engine to the electrical unit.

We therefore ran the direct-connected Skinner Engine at 277 R.P.M. with the field switch pulled out, and took 3 indicator cards. In order to obtain as accurate results as possible, 3 cards were taken at each load, and each card was measured up with a planimeter by all four testers, and the average of the 12 results taken as final.

As may be seen from the scheme of connections, three 50 - 1 current transformers were connected in the three phases of the alternator. These were placed at the machine, where the main leads from the switch board are fatened to the alternator. By means of $\frac{1}{0}$" lugs the transformers were securely fastened into the lines. The secondaries of these transformers were connected to a 6 pole double throw switch, which if thrown to the left would connect the six terminals of the A.C. ammeters

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in the secondaries of the transformers, and if thrown to the right, would connect the six terminals of the current coils of the 3 Wattmeters in the secondaries. This device saved a great deal of time, and gave a very simple method of getting all six readings without changing connections. The potential posts of the wattmeters were connected respectively to phase and neutral.

The six pole double throw switch was fastened to a small board, on which switches providing for connections to voltmeters were also placed. By proper manipulation of these, the voltage from any phase to neutral, as well as from any phase to phase, could readily be obtained from the one voltmeter. A direct current ammeter was connected into the circuit of the 3.8 K.W. Crocker-Wheeler exciter, and readings of the field current were taken at each change of load. The frequency meter was connected between phases through an improvised lamp rack, consisting of 2 110 volt, 16 candle power incandescent lamps in series, in order to protect the frequency-meter, which is constructed for a voltage not higher than 110.

A perfectly new Thompson external spring indicator was used on the cylinder of the Skinner engine to determine the horse-power input. The spring of the indicator used was 100 pounds, so that each inch of ordinate on the cards was equivalent to 100# pressure. The average length of the cards was 4.63",

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the reducing factor therefore being, 15 divided by 4.53, which is equal to 3.33.

After obtaining the friction loss of the engine which was calculated to be 10.04 Horse-power, the load on the other generator, which at that time consisted of all the lights of the station, was thrown to the tested machine. Nine different steps were taken, the different loads being obtained by throwing in various combinations of induction motors on to the alternator circuit. During the test the frequency of the alternator altered only from 120 to 121 alternations, or from 277 R.P.M. to 279.2 R.P.M. The field current changed from 23.3 amperes at light loads to 35.4 at full load. The voltages from phase to neutral ranged from 126 at full load to 137 at light loads, while the phase to phase voltage was between the limits of 215.2 and 232.2. All ammeter readings were taken simultaneously, as well as all the wattmeter readings.

Our calculations show that the efficiency varied between 71.4% and 87.4%, the power factor of the circuit being between .6603 and .7632. The low "power factor" is caused by the great number of induction motors, causing a considerable lag of the current behind the electromotive force. The per cent regulation of the machine varied from 17.95% at light loads to 73.25 per cent at full load.

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Sample Calculations of the efficiency test of the alternator follow:

LOAD #1.

| Readings. | | | As Taken. | Corrected. |
|---|---|---|---|---|
| A | #1 | | 1.19 | 59.0 |
| A | #2 | | 1.02 | 51.5 |
| A | #3 | | 1.13 | 56.5 |
| W | #1 | | 105 | 5350 |
| W | #2 | | 58 | 3130 |
| W | #3 | | 77 | 3850 |
| V | #1 | Phase to Neutral. | 129 | 131 |
| V | #2 | | 130 | 132 |
| V | #3 | | 128.3 | 130.3 |
| F | | | 60 | 60 |
| I | Field | | 23.3 | 23.5 |
| V | 1-2 | | 228 | 232 |
| V | 2-3 | | 224.5 | 228.5 |
| V | 3-1 | | 223.4 | 227.4 |

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Mean ordinate = Crank End $\frac{.815}{4.31}$ = .1193

Head End $\frac{.686}{4.31}$ = .1594

Scale of Spring = 100#

.1193 x 100 = 11.93# = M.E.P. C.E.

.1594 x 100 = 15.94# = M.E.P. H.E.

Length of stroke = 15"

Diameter of piston = 12"

Area of piston H.E. = 113.1 sq."

Area of piston C. E. = 111.3 sq."

Revolutions per minute = 277.

$$\text{Horse-power}_{\text{C.E.}} = \frac{\text{PLAN}}{33000}$$

$$= \frac{11.93 \times 1.25 \times 113.1 \times 277}{33000} = 13.91$$

$$\text{Horse-power}_{\text{H.E.}} = \frac{\text{PLAN}}{33000}$$

$$= \frac{15.94 \times 1.25 \times 111.34 \times 277}{33000} = 18.93$$

Total Horse-power input from indicator cards=

= 13.91 plus 18.93

= 32.84.

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Areas of Indicator Cards.

| | | | | |
|---|---|---|---|---|
| 1. | Crank. | .44 sq." | Head | .67 sq." |
| 2. | | .71 | | .77 |
| 3. | | .46 | | .61 |
| 4. | | .45 | | .70 |
| Av. | | .515 | | .688. |

Average length of card(head and crank).

4.418".

$E_1 I_1$ = 232 x 59 = 13688.

$E_2 I_2$ = $228\frac{1}{2}$ x $51\frac{1}{2}$ = 11768.

$E_3 I_3$ = $227\frac{1}{2}$ x $56\frac{1}{2}$ = 12848.

Average EI = 12768.

$$\text{Power factor} = \frac{\text{Watts Output.}}{1.73 \text{ EI}}$$

Watts output = $W_1 + W_2 + W_3$.

= 12350.

$$\text{Power factor} = \text{cosine } \phi = \frac{12350}{1.73 \times 12766} = .5565$$

Watts input = Horse power input x 746.

3294 x 746 = 17007.

% Efficiency = Watts output ÷ Watts input

= 12350 ÷ 17007.

= 72.6%.

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In order to obtain the regulation of the alternator, the saturation curves, and synchronous reactance curves of the generator had to be drawn. To obtain the necessary data for these curves the alternator was short-circuited through three ammeters and readings were taken, of the field current corresponding to various armature currents. This gave us data to plot a curve relating armature current and field current. With the same range of field currents values of the induced electromotive force were taken. Plotting this latter curve gives us what is termed the "synchronous reactance" curve of the machine.

We obtained the resistances of both the field winding (4.05 ohms) and of the armature winding ( .032) from the Crocker-Wheeler Company of New Jersey, the manufacturers of the machine. We calculated the reactance of the machine to be .8435 ohms. From this data the resistance drops and reactance drops could be calculated for any load, the regulation being graphically calculated, the power factor at each load being taken into account as shown in the accompanying diagrams.

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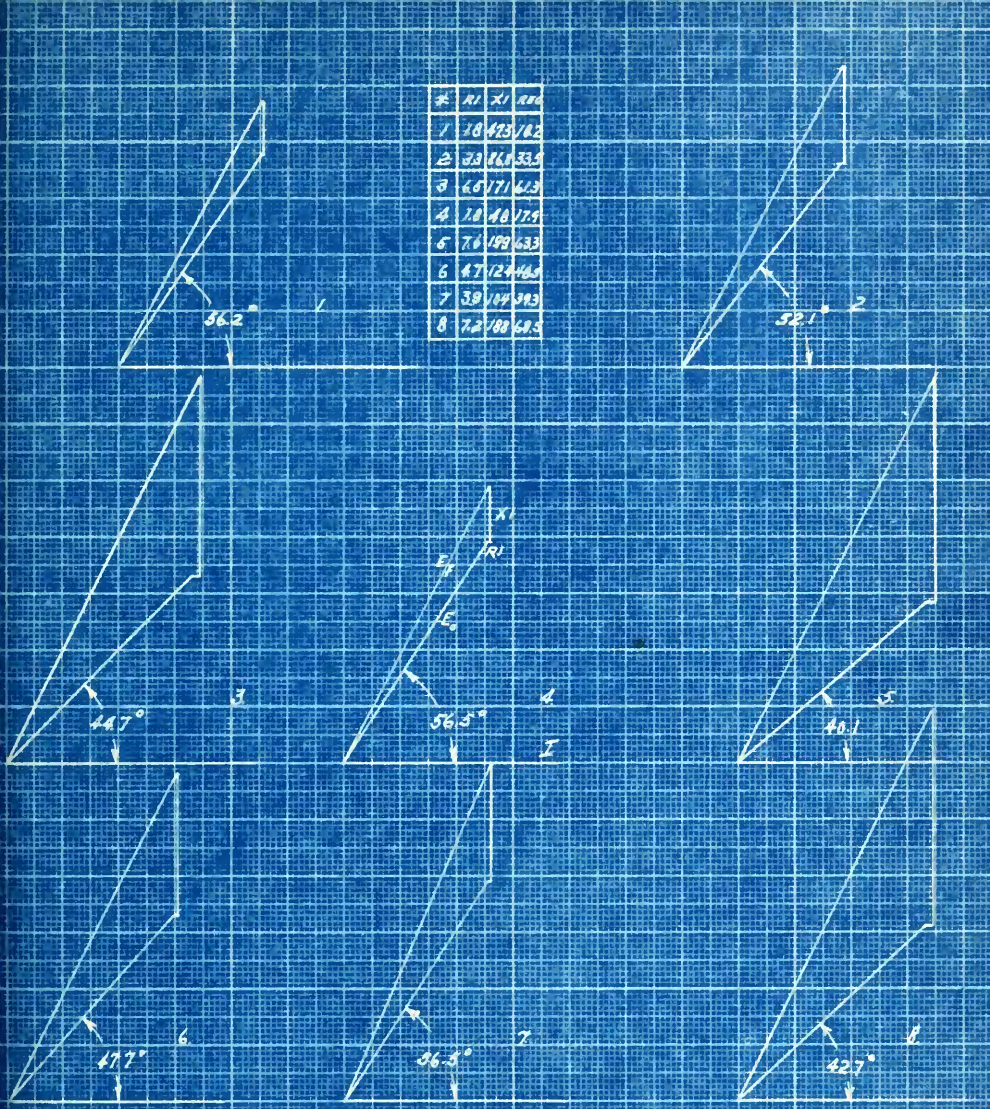
| # | R1 | X1 | Z1 |
|---|---|---|---|
| 1 | 1.8 | 4.23 | 4.6 |
| 2 | 3.3 | 16.8 | 33.5 |
| 3 | 4.6 | 7.1 | 6.3 |
| 4 | 1.0 | 4.8 | 7.9 |
| 5 | 7.6 | 1.99 | 6.33 |
| 6 | 4.7 | 12.4 | 14.5 |
| 7 | 3.9 | 1.99 | 3.93 |
| 8 | 7.2 | 1.80 | 6.5 |




GRAPHICAL REPRESENTATION
OF
GEN. VOLTAGE REGULATION
SCALE 1 MM. = 2.5 VOLTS
X = .8435 Ω R = .032 Ω

CURVE SHEET No. 29

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## COST OF PRODUCING POWER.

The cost of producing the electrical energy at the switchboard was calculated from the indicator cards, taken on the engine during the test. Only the cost of evaporating the water was used in figuring the cost per Kilowatt-hour. All calculations were made on the assumption that the same amount of work was done in both ends of the cylinder. This is slightly in error , but not enough to throw the results off to any appreciable extent.

Sample Calculation of Run #5.

The following data was obtained from indicator cards, the values being found on each of the three cards, and the average used in the calculations. Absolute pressure in cylinder at points of

Cut-off = 98.36 Release = 44.03 Compression= 39.03

The above values indicate pounds per square inch. Piston displacement in % of stroke, including clearance of 10%.

Cut-off = 36.75% Release = 86.20% Compression = 20.6

The volumes displaced in cubic feet are as follows:

Cut-off = .3608 Release = .845 Compression = .202

These values represent the volumes of steam in the cylinder at the various points in the stroke. The weight of steam per cubic foot at the various pressures in the cylinder,which were obtained from a steam table were as follows:

Cut-off = .2675# Release = .1393# Compression = .12#

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The products of these weights and the corresponding volumes will give the weight of steam in the cylinder at the various parts of the stroke. These work out to be, at

Cutoff = .0935# Release = .1140# Compression = .0265#

The amount of steam used per stroke is found from the foregoing data, at points of cut-off and release by subtracting weight in cylinder at compression from weight at cut-off and release.

Cut-off = .0661 pounds Release = .0920 pounds.

The water rate is determined by multiplying the weight of steam used per stroke by the number of R.P.M. multiplied by 60 and dividing by the Indicated Horse-power.

Water rate at Cut-off = 10#

Water rate at Release = 13.95#

Average Water Rate 11.975#

This value takes into consideration only one end of the cylinder, and since we assume equal amounts of work to be done in each end of the cylinder the total amount of steam used per Indicated Horse-power is equal to 23.95 pounds. The steam used per Kilowatt Hour was found in the same manner, by using K.W.Hour instead of I.H.P.Hour in the previous water-rate formula.

Water rate per Kilowatt-Hour = 40.54 pounds.

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The cost per Kilowatt-Hour was based on the cost of evaporating the water entirely, and does not include the handling of coal and tending of boiler. This was done because the steam must be had for making ice, and all energy that is taken away from it between the boilers and condensers, is money saved. Therefore the cost of generating energy does not effect the cost of operating the plant, and for that reason the economy of the driving engine is not of any great value. About the only thing gained or brought out by the cost and economy data is the variation for various loads on the machine.

Cost of Evaporation per pound = $.1128 per 1000#

Product of the cost per pound, of evaporation, and pounds of steam used per Kilowatt-Hour, gives the cost per Kilo-watt-Hour.

.1128 x 40.64 = 4.61¢ per Kilowatt-Hour.

The average load on the machine is about 50 Kilowatts, and this is about the point at which the maximum economy is obtained, so that the machine is running at its best practically all of the time, since the load is continuous for 24 hours per day.

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# TEST OF A 75 KW CROCKER-WHEELER ALTERNATOR

JANUARY 27 1909

RUNNING LOG

| $A_1$ | $A_2$ | $A_3$ | $W_1$ | $W_2$ | $W_3$ | $V_{1-N}$ | $V_{2-N}$ | $V_{3-N}$ | $V_{1-2}$ | $V_{2-3}$ | $V_{3-1}$ | ~ | FLD CURRENT | MOTORS USED AS LOAD | LOCATION OF MOTORS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 119 | 1.02 | 1.13 | 105 | 58 | 77 | 129 | 130 | 1283 | 228 | 2245 | 2234 | 60 | 233 | LIGHT LOAD. | ENTIRE PLANT |
| 214 | 1.98 | 2.07 | 184 | 148 | 157 | 1321 | 133 | 1322 | 2254 | 2240 | 2232 | 60 | 24.7 | ASH MOTOR | ASH TOWER. |
| 416 | 4.01 | 4.06 | 4045 | 375 | 381.5 | 1354 | 1356 | 1355 | 2310 | 2300 | 2291 | 60 | 354 | CENTRIFUGAL PUMP. | ENGINE ROOM. |
| 450 | 4.40 | 4.48 | 446.0 | 416 | 422.0 | 132.0 | 1322 | 1321 | 2240 | 2244 | 2240 | 60 | 34.75 | COAL CONVEYORS | COAL BUNKERS-BOILER ROOM. |
| 4.78 | 4.65 | 4.71 | 468.0 | 439 | 446.0 | 126.3 | 1260 | 127.0 | 2161 | 2156 | 2152 | 60.5 | 33.5 | AIR COMPRESSOR | ENGINE ROOM |
| 2.55 | 2.38 | 2.47 | 200.0 | 166 | 1725 | 1354 | 1352 | 1345 | 2300 | 2294 | 2281 | 60.5 | 27.5 | ASH + AIR COMPRESSOR | ENG.RM. + ASH TOWER. |
| 3.02 | 2.87 | 2.92 | 267.5 | 237 | 247.0 | 131.0 | 131.0 | 130.9 | 222.4 | 2216 | 2201 | 60.5 | 27.75 | AIR COMPRESSOR | ENGINE ROOM. |
| 121 | 1.04 | 1.16 | 106.0 | 59 | 81.0 | 136.0 | 137.0 | 136.0 | 2322 | 2310 | 2291 | 60.5 | 23.40 | LIGHT LD + COAL CONVEYOR | BOILER ROOM. |

CORRECTED VALUES.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 58.0 | 51.5 | 56.5 | 5350 | 3150 | 3850 | 131 | 132 | 130.3 | 232 | 228.5 | 2274 | 60 | 23.5 | THE CURRENT INDICATED BY THE |
| 108.0 | 99.5 | 103.5 | 9400 | 7850 | 7800 | 134 | 1349 | 134 | 2294 | 2280 | 2262 | 60 | 24.9 | AMMETERS WAS .02 OF THE ACTUAL |
| 208.0 | 200.5 | 203.0 | 20600 | 19150 | 18025 | 135 | 1352 | 1352 | 235.0 | 2340 | 2337 | 60 | 35.8 | VALUE, 50 TO 1 CURRENT TRANSFORMERS |
| 225.0 | 220.0 | 224.0 | 22650 | 21200 | 21000 | 134 | 134.2 | 134 | 228.0 | 228.4 | 228.0 | 60 | 35.15 | HAVING BEEN PUT IN THE LINES. AS THE |
| 238.0 | 232.5 | 235.5 | 23850 | 22425 | 22150 | 1283 | 1281 | 129 | 220.1 | 2196 | 2192 | 60.5 | 33.80 | CURRENT COILS OF THE WATTMETERS |
| 128.0 | 119.8 | 123.5 | 10175 | 8750 | 8600 | 135 | 1349 | 1345 | 2340 | 2334 | 2321 | 60.5 | 27.75 | WERE CONNECTED ACROSS THE SECONDARIES |
| 151.5 | 143.5 | 146.0 | 13600 | 17300 | 12850 | 133 | 133 | 131.8 | 226.4 | 225.6 | 2241 | 60.5 | 28.05 | THEY INDICATED ONLY .02 OF THE ACTUAL |
| 60.0 | 52.0 | 58.0 | 5450 | 3200 | 4050 | 1354 | 136.5 | 1354 | 2362 | 2350 | 2331 | 60.5 | 23.6 | WATTS. |

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# HORSE POWER INPUT FROM INDICATOR CARDS - ALTERNATOR TEST

| Lead and Card No. | Areas of Cards in Square Inches. Crank Head. 1 FITCH | 2 JONES | 3 HEIM | 4 HIRSCHFELD | Average | Head End. 1 FITCH | 2 JONES | 3 HEIM | 4 HIRSCHFELD | Average | Length of Card | Length Mean Ordinate H.E. | Length Mean Ordinate C.E. | Mean Effective Pressure H.E. | Mean Effective Pressure C.E. | Area of Piston | Number of Revolutions | INDICATED HORSE POWER C.E. | INDICATED HORSE POWER H.E. | INDICATED HORSE POWER Total | Total Watts Input |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NO LOAD | .14 | .14 | .14 | .14 | .14 | .20 | .20 | .22 | .22 | .21 | 4.421 | | | | | SCALE OF INDICATOR CARDS LENGTH OF STROKE 1" | | | | | |
| a | .21 | .20 | .12 | .15 | .17 | .31 | .25 | .18 | .23 | .243 | 4.421 | .0524 | .0338 | 5.24 | 3.28 | | 277 | 3.82 | 6.22 | 10.04 | 7490 |
| b | .11 | .14 | .06 | .10 | .127 | .21 | .28 | .23 | .27 | .243 | 4.421 | | | | | | | | | | |
| 1 | .44 | .71 | .46 | .45 | .515 | .67 | .77 | .61 | .70 | .688 | 4.316 | .1594 | .1193 | 15.94 | 11.909 | | 277 | 13.91 | 18.93 | 32.84 | 24497 |
| 2 | .97 | 1.00 | .91 | 1.00 | .970 | 1.04 | 1.26 | 1.01 | 1.10 | 1.093 | 4.586 | | | | | | | | | | |
| a | .96 | .93 | .91 | .91 | .927 | .98 | 1.11 | .94 | 1.00 | 1.008 | 4.586 | .2307 | .2041 | 23.07 | 20.41 | | 277 | 23.79 | 27.41 | 51.20 | 38195 |
| b | .97 | 1.01 | .91 | 1.00 | .972 | 1.02 | 1.16 | 1.08 | 1.05 | 1.078 | 4.586 | | | | | | | | | | |
| 3 | 2.00 | 2.10 | 2.00 | 2.04 | 2.035 | 2.01 | 2.05 | 2.02 | 2.10 | 2.045 | 4.587 | | | | | | | | | | |
| a | 2.04 | 2.00 | 2.09 | 2.10 | 2.057 | 1.97 | 2.00 | 1.91 | 1.98 | 1.965 | 4.587 | .4331 | .4463 | 43.31 | 44.63 | | 277 | 52.11 | 51.49 | 103.60 | 77286 |
| b | 2.02 | 2.06 | 2.04 | 2.08 | 2.050 | 1.85 | 2.05 | 1.91 | 2.00 | 1.953 | 4.587 | | | | | | | | | | |
| 4 | 2.04 | 2.01 | 2.12 | 2.10 | 2.068 | 2.08 | 2.12 | 2.02 | 2.06 | 2.070 | 4.437 | | | | | | | | | | |
| a | 2.13 | 2.10 | 2.06 | 2.20 | 2.122 | 1.97 | 2.08 | 2.04 | 2.01 | 2.025 | 4.437 | .4582 | .4721 | 45.82 | 47.21 | | 277 | 55.03 | 54.48 | 109.51 | 81694 |
| b | 2.04 | 2.07 | 2.17 | 2.10 | 2.035 | 2.00 | 2.02 | 2.01 | 2.00 | 2.008 | 4.437 | | | | | | | | | | |
| 5 | 2.22 | 2.32 | 2.23 | 2.24 | 2.302 | 2.08 | 2.26 | 2.17 | 2.23 | 2.160 | 4.408 | | | | | | | | | | |
| a | 2.31 | 2.31 | 2.30 | 2.33 | 2.312 | 2.17 | 2.18 | 2.13 | 2.15 | 2.150 | 4.408 | .4932 | .5236 | 49.32 | 52.36 | | 279.2 | 61.58 | 59.06 | 120.64 | 89997 |
| b | 2.32 | 2.28 | 2.32 | 2.32 | 2.310 | 2.19 | 2.34 | 2.16 | 2.15 | 2.210 | 4.408 | | | | | | | | | | |
| 6 | 1.00 | 1.08 | 1.04 | 1.06 | 1.045 | 1.08 | 1.10 | 1.00 | 1.05 | 1.058 | 4.434 | | | | | | | | | | |
| a | 1.00 | 1.15 | .93 | 1.04 | 1.030 | 1.09 | 1.10 | 1.08 | 1.14 | 1.103 | 4.434 | .2429 | .2329 | 24.29 | 23.29 | | 279.2 | 27.42 | 29.08 | 56.50 | 42149 |
| b | 1.01 | 1.06 | .98 | 1.04 | 1.025 | 1.08 | 1.10 | 1.03 | 1.072 | 1.07 | 4.434 | | | | | | | | | | |
| 7 | 1.30 | 1.34 | 1.29 | 1.36 | 1.322 | 1.37 | 1.53 | 1.31 | 1.40 | 1.443 | 4.531 | | | | | | | | | | |
| a | 1.32 | 1.34 | 1.29 | 1.34 | 1.322 | 1.32 | 1.52 | 1.22 | 1.37 | 1.358 | 4.531 | .3051 | .2902 | 30.51 | 29.02 | | 279.2 | 34.23 | 36.56 | 70.79 | 52809 |
| b | 1.32 | 1.30 | 1.24 | 1.35 | 1.302 | 1.33 | 1.50 | 1.29 | 1.42 | 1.385 | 4.531 | | | | | | | | | | |
| 8 | .42 | .63 | .54 | .62 | .552 | .65 | .82 | .70 | .74 | .753 | 4.565 | | | | | | | | | | |
| a | .55 | .61 | .49 | .59 | .560 | .64 | .94 | .67 | .68 | .733 | 4.565 | .1629 | .1222 | 16.29 | 12.22 | | 279.2 | 14.39 | 19.49 | 33.88 | 25274 |
| b | .56 | .60 | .51 | .59 | .562 | .64 | .90 | .69 | .75 | .745 | 4.565 | | | | | | | | | | |

DATA SHEET No 3.

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## DATA TAKEN FROM INDICATOR CARDS OBTAINED DURING ALTERNATOR TEST.

| NUMBER OF CARD | ABSOLUTE PRESSURE AT | | | PISTON DISPLACEMENT % OF STROKE AT | | |
|---|---|---|---|---|---|---|
| Nº | CUT-OFF | RELEASE | COMPRESSION | CUT-OFF | RELEASE | COMPRESSION |
| 1 | 92.7 | 17.7 | 85.7 | 11.78 | 83.9 | 11.11 |
| 1a | 94.7 | 17.7 | 86.7 | 12. | 76.6 | 10.88 |
| 1b | 67.7 | 17.7 | 83.7 | 14.45 | 76.6 | 12.00 |
| 2 | 69.7 | 17.7 | 57.7 | 18.65 | 90.7 | 15.11 |
| 3 | 90.7 | 27.7 | 52.7 | 22.22 | 82.4 | 18.12 |
| 3a | 94.7 | 30.7 | 57.7 | 20.67 | 76.8 | 15.78 |
| 3b | 84.7 | 27.7 | 47.7 | 25.5 | 76.3 | 17.71 |
| 4 | 87.7 | 40.7 | 40.7 | 44.9 | 89.3 | 23.3 |
| 4a | 97.7 | 37.7 | 39.7 | 37.3 | 89.7 | 20.65 |
| 4b | 94.7 | 40.7 | 42.7 | 37.3 | 90. | 17.33 |
| 5 | 99.7 | 44.7 | 39.7 | 36.42 | 86.3 | 20.22 |
| 5a | 99.7 | 44.7 | 37.7 | 36.22 | 85.2 | 21.78 |
| 5b | 95.7 | 42.7 | 39.7 | 37.60 | 87.1 | 19.79 |
| 6 | 94.7 | 45.7 | 42.7 | 40.63 | 90.8 | 16.66 |
| 6a | 90.7 | 45.7 | 45.7 | 47.08 | 92.3 | 14.00 |
| 6b | 92.7 | 43.7 | 42.7 | 43.1 | 95.1 | 15.57 |
| 7 | 76.7 | 29.7 | 43.7 | 27.06 | 82.4 | 17.12 |
| 7a | 76.7 | 27.7 | 45.7 | 26.19 | 87.1 | 17.56 |
| 7b | 79.7 | 29.7 | 34.7 | 27.38 | 81.5 | 25.39 |
| 8 | 81.7 | 30.7 | 29.7 | 33.80 | 88.4 | 33.1 |
| 8a | 85.7 | 30.7 | 32.7 | 33.33 | 91.1 | 32.68 |
| 8b | 90.7 | 29.7 | 28.7 | 27.31 | 89.9 | 33.32 |
| 9 | 74.7 | 23.7 | 42.7 | 23.89 | 80.7 | 26.9 |
| 9a | 68.7 | 23.7 | 36.7 | 25.5 | 77.1 | 30.00 |
| 9b | 68.7 | 24.7 | 37.7 | 23.32 | 80.7 | 26.89 |

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# EFFICIENCY TEST OF CROCKER WHEELER 75 KV.A 60 ~ 240 V ALTERNATOR

| $E_1 I_1$ | $E_2 I_2$ | $E_3 I_3$ | AVERAGE $EI$ | WATTS OUTPUT | POWER FACTOR COS $\theta$ | INDICATOR CARDS LENGTH | M.E.P. | I.H.P. | EQUIVALENT WATTS INPUT | PERCENT EFFICIENCY | PERCENT REGULATION | ANGLE OF LAG $-\theta^\circ$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13688 | 11768 | 12848 | 12768 | 12350 | .5565 | 4.316 | 27.87 | 32.84 | 17007 | 72.6 | 18.23 | 56.2 |
| 24775 | 22686 | 23412 | 23624 | 25050 | .6125 | 4.586 | 43.48 | 51.20 | 30725 | 81.5 | 33.49 | 52.1 |
| 48880 | 46917 | 47319 | 47705 | 58775 | .7120 | 4.587 | 87.94 | 103.6 | 68786 | 84.2 | 61.29 | 44.7 |
| 51300 | 50248 | 51072 | 50873 | 64850 | .7365 | 4.437 | 93.03 | 109.51 | 74204 | 87.4 | 68.51 | 42.7 |
| 52704 | 51057 | 51622 | 51794 | 68425 | .7632 | 4.408 | 101.68 | 120.64 | 82507 | 83.0 | 73.25 | 40.1 |
| 29962 | 27891 | 28664 | 28836 | 27525 | .5518 | 4.434 | 47.58 | 56.60 | 34657 | 79.6 | 39.25 | 56.5 |
| 34300 | 32374 | 32719 | 33131 | 38750 | .6741 | 4.631 | 59.63 | 70.79 | 45319 | 85.3 | 48.45 | 47.7 |
| 14168 | 12220 | 13620 | 13300 | 12700 | .5503 | 4.665 | 28.51 | 33.88 | 17784 | 71.4 | 17.95 | 56.6 |

DATA SHEET No 4.

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# DATA FOR SYNCHRONOUS REACTANCE AND SATURATION CURVES.

## CROCKER-WHEELER

### ACTUAL

| $I_1$ | $I_2$ | $I_3$ | Av I | $I_f$ | $E_o$ | $I_f$ |
|---|---|---|---|---|---|---|
| .9 | 85 | .86 | .87 | 2.75 | 44 | 3.05 |
| 1.29 | 1.30 | 1.28 | 1.29 | 4.30 | 56 | 4.00 |
| 1.50 | 1.48 | 1.47 | 1.48 | 4.75 | 73 | 4.95 |
| 1.82 | 1.85 | 1.82 | 1.82 | 5.55 | 90 | 5.80 |
| 2.20 | 2.21 | 2.21 | 2.21 | 6.75 | 108 | 7.00 |
| 2.70 | 2.68 | 2.69 | 2.69 | 8.20 | 121.5 | 7.90 |
| 3.08 | 3.08 | 3.10 | 3.09 | 9.25 | 137.5 | 8.95 |
| 3.52 | 3.50 | 3.48 | 3.50 | 10.40 | 154.0 | 10.00 |
| 3.87 | 3.85 | 3.95 | 3.96 | 11.60 | 173. | 11.40 |
| 4.46 | 4.48 | 4.50 | 4.46 | 12.85 | 182.3 | 12.05 |
| | | | | | 195.0 | 13.05 |
| | | | | | 210.0 | 14.35 |
| | | | | | 222.0 | 15.65 |
| | | | | | 230.7 | 16.75 |
| | | | | | 242 | 18.50 |
| | | | | | 249. | 19.70 |

### CORRECTED

| $I_1$ | $I_2$ | $I_3$ | Av I | $I_f$ | $E_o$ | $I_f$ |
|---|---|---|---|---|---|---|
| 44 | 43.5 | 43.5 | 43.6 | 2.65 | 43.9 | 2.95 |
| 64.5 | 64.5 | 64.5 | 64.5 | 4.25 | 55.9 | 3.95 |
| 75.0 | 74.0 | 74.5 | 74.5 | 4.72 | 72.1 | 4.93 |
| 91.5 | 92.5 | 92.0 | 92.0 | 5.54 | 89.1 | 5.79 |
| 111.1 | 111.5 | 111. | 111.2 | 6.75 | 107.2 | 7.00 |
| 136 | 135.5 | 135.5 | 135.7 | 8.20 | 120.5 | 7.90 |
| 156 | 155.5 | 156.5 | 156.0 | 9.25 | 136.4 | 8.96 |
| 172 | 175.5 | 175. | 174.2 | 10.40 | 152.9 | 10.00 |
| 198.5 | 196.5 | 197.5 | 197.5 | 11.60 | 171.8 | 11.40 |
| 223 | 223.5 | 225. | 223.8 | 12.95 | 181.7 | 12.05 |
| | | | | | 193.8 | 13.05 |
| | | | | | 208.7 | 14.35 |
| | | | | | 220.5 | 15.65 |
| | | | | | 229.0 | 16.75 |
| | | | | | 240.2 | 18.70 |
| | | | | | 247.0 | 20.0 |

## BULLOCK.

### ACTUAL

| $I_1$ | $I_2$ | $I_3$ | Av I | $I_f$ | $E_o$ | $I_f$ |
|---|---|---|---|---|---|---|
| .50 | .50 | .35 | .45 | .8 | 30.0 | 1 |
| .73 | .73 | .65 | .70 | 1.2 | 42.0 | 1.5 |
| .86 | .84 | .81 | .84 | 1.4 | 52.0 | 1.85 |
| 1.95 | 1.92 | 1.93 | 1.93 | 3.0 | 76.0 | 2.75 |
| 2.28 | 2.26 | 2.26 | 2.27 | 3.6 | 88.0 | 3.20 |
| 2.48 | 2.50 | 2.49 | 2.49 | 4.0 | 98.0 | 3.55 |
| 2.59 | 2.61 | 2.60 | 2.60 | 4.2 | 115.0 | 4.25 |
| 2.83 | 2.85 | 2.86 | 2.85 | 4.5 | 127.8 | 4.85 |
| 2.99 | 3.02 | 3.00 | 3.00 | 4.75 | 155.0 | 6.26 |
| 3.15 | 3.21 | 3.20 | 3.19 | 5.00 | 173.0 | 7.50 |
| | | | | | 184.0 | 8.50 |
| | | | | | 194.0 | 9.55 |
| | | | | | 210.0 | 12.00 |
| | | | | | 224.0 | 15.00 |
| | | | | | 237.5 | 18.30 |
| | | | | | 244.0 | 20.20 |

### CORRECTED

| $I_1$ | $I_2$ | $I_3$ | Av I | $I_f$ | $E_o$ | $I_f$ |
|---|---|---|---|---|---|---|
| 23 | 26.5 | 19.0 | 23.0 | .78 | 30.0 | .98 |
| 35 | 36.5 | 34.0 | 35.2 | 1.18 | 41.9 | 1.48 |
| 42 | 41.5 | 41.0 | 41.5 | 1.39 | 51.9 | 1.84 |
| 98.5 | 97.0 | 97.5 | 97.75 | 2.90 | 75.2 | 2.69 |
| 114.5 | 115.0 | 113.5 | 114.4 | 3.55 | 87.1 | 3.11 |
| 124.5 | 125.5 | 125 | 125 | 4.00 | 97.1 | 3.50 |
| 130.5 | 131.0 | 130.5 | 130.7 | 4.20 | 114.0 | 4.25 |
| 143.0 | 143.0 | 144.5 | 143.5 | 4.50 | 126.7 | 4.85 |
| 150.0 | 152.5 | 151. | 151.2 | 4.75 | 153.8 | 6.26 |
| 158.0 | 161.5 | 160.5 | 160.0 | 5.00 | 171.7 | 7.50 |
| | | | | | 182.6 | 8.50 |
| | | | | | 192.4 | 9.55 |
| | | | | | 208.7 | 12.00 |
| | | | | | 222.6 | 15.00 |
| | | | | | 235.8 | 18.35 |
| | | | | | 242.0 | 20.80 |

DATA SHEET #2 5.

CROCKER-WHEELER

| $I_f$ | $I_a$ | E | Z | R | RI | E-RI | L |
|---|---|---|---|---|---|---|---|
| 305 | 50 | 439 | 877 | 16 | .032 | 42.3 | 845 |
| 4.00 | 675 | 559 | .828 | 2.16 | .032 | 53.74 | 796 |
| 495 | 84 | 721 | .857 | 269 | .032 | 69.41 | .825 |
| 5.80 | 99 | 891 | .900 | 3.17 | .032 | 85.93 | .868 |
| 700 | 119 | 1072 | .900 | 381 | .032 | 103.39 | .868 |
| 790 | 135 | 1205 | .892 | 4.32 | .032 | 116.18 | .860 |
| 895 | 154 | 1364 | .885 | 4.93 | .032 | 131.47 | .853 |
| 1000 | 175 | 1529 | .892 | 550 | .032 | 147.49 | .860 |
| 1140 | 196 | 1718 | .878 | 628 | .032 | 165.52 | .846 |
| 1205 | 208 | 1817 | .874 | 666 | .032 | 175.16 | .842 |
| 1365 | 226 | 1938 | .858 | 725 | .032 | 186.55 | .826 |
| | | | | | | | |

BULLOCK

| $I_f$ | $I_a$ | E | Z | R | RI | E-RI | L |
|---|---|---|---|---|---|---|---|
| 10 | 32.5 | 30 | 924 | .0269 | .875 | 29.15 | .897 |
| 15 | 48.5 | 419 | 863 | .0269 | 1.30 | 40.69 | .837 |
| 1.85 | 59.5 | 519 | .876 | .0269 | 1.60 | 50.30 | .845 |
| 2.75 | 88.5 | 752 | .850 | .0269 | 2.38 | 72.82 | .824 |
| 3.20 | 103.2 | 871 | .844 | .0269 | 2.78 | 84.32 | .816 |
| 3.55 | 114.4 | 971 | .848 | .0269 | 3.08 | 94.02 | .821 |
| 4.25 | 137.0 | 114 | .832 | .0269 | 3.69 | 110.31 | 803 |
| 4.15 | 156.0 | 1267 | 811 | .0269 | 4.20 | 122.51 | 785 |
| 6.20 | 200.0 | 1538 | .768 | .0269 | 5.39 | 128.41 | 742 |

DATA SHEET No 5

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# ECONOMY AND COST DATA FOR SKINNER ENGINE AND CROCKER WHEELER 75 KVA ALTERNATOR

| NUMBER OF RUN. | AVERAGE ABSOLUTE PRESSURES AT | | | AVERAGE PISTON DISPLACEMENT IN % OF STROKE AT | | | AVERAGE PISTON DISPLACEMENT IN CU. FT. AT | | | WEIGHT OF STEAM PER CUBIC FOOT AT PRESSURE IN CYLINDER AT | | | WEIGHT OF STEAM IN CYLINDER AT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nº | CUT-OFF | RELEASE | COMPRESSION | CUT-OFF | RELEASE | COMPRESSION | CUT-OFF | RELEASE | COMPRESSION | CUT-OFF | RELEASE | COMPRESSION | CUT-OFF | RELEASE | COMPRESSION |
| 1 | 85 | 17.7 | 85.3 | 12.74 | 79.03 | 11.33 | .125 | .776 | .1112 | .2289 | .07896 | .2296 | .02863 | .0613 | .02555 |
| 2 | 69.7 | 17.7 | 57 | 18.65 | 90.7 | 15.11 | .183 | .890 | .1483 | .1958 | .07996 | .1696 | .0358 | .0703 | .02515 |
| 3 | 90.03 | 28.7 | 52.7 | 22.80 | 78.5 | 17.2 | .2239 | .77 | .1688 | .2396 | .1049 | .1586 | .05355 | .0807 | .02673 |
| 4 | 93.7 | 39.7 | 41.03 | 37.83 | 89.7 | 20.43 | .3714 | .88 | .2008 | .2476 | .1297 | .1320 | .092 | .1140 | .02652 |
| 5 | 98.36 | 44.03 | 39.03 | 36.75 | 86.2 | 20.59 | .3608 | .845 | .2020 | .2575 | .1393 | .1282 | .093 | .1179 | .0259 |
| 6 | 92.7 | 46.03 | 43.7 | 43.6 | 92.7 | 15.41 | .4280 | .91 | .1512 | .2454 | .1416 | .1386 | .1050 | .1290 | .021 |
| 7 | 77.7 | 29.03 | 41.36 | 26.88 | 83.7 | 20.02 | .2640 | .821 | .1967 | .2132 | .1056 | .1334 | .0563 | .0866 | .02625 |
| 8 | 96.03 | 30.36 | 30.36 | 31.48 | 89.8 | 33.03 | .3090 | .881 | .3242 | .2312 | .1087 | .1087 | .0715 | .0957 | .03512 |
| 9 | 70.7 | 24.36 | 39.03 | 24.25 | 79.5 | 27.93 | .2378 | .78 | .2740 | .1980 | .09494 | .1282 | .047 | .0741 | .03615 |

| WEIGHT OF STEAM IN CYLINDER AFTER DEDUCTING WEIGHT OF STEAM AT COMPRESSION | | INDICATED HORSEPOWER OF ENGINE. | KILOWATTS OUTPUT | SPEED IN R.P.M | STEAM USED PER I.H.P HR. ASSUMING SAME AMOUNT OF WORK DONE IN H.E. AND C.E | | | | STEAM USED PER KW HR. ASSUMING SAME AMOUNT OF WORK DONE IN H.E AND C.E. | | | | COST PER KW. HR. CENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CUT-OFF | RELEASE | I.H.P. | KW | S. | CUT-OFF | RELEASE | AVERAGE | TOTAL | CUT-OFF | RELEASE | AVERAGE | TOTAL | K |
| .00307 | .03575 | 10.04 | 0 | 277 | 5.1 | 59 | 32.04 | 64.08 | — | — | — | — | — |
| .01065 | .04515 | 32.84 | 12.35 | 277 | 5.38 | 23.6 | 14.49 | 28.98 | 14.32 | 60.9 | 37.61 | 75.22 | 8.53 |
| .02682 | .05397 | 51.20 | 25.05 | 277 | 8.7 | 18.15 | 13.425 | 26.85 | 17.85 | 35.8 | 26.87 | 53.74 | 6.11 |
| .06585 | .08748 | 103.6 | 58.775 | 277 | 10.55 | 14.05 | 12.3 | 24.6 | 18.55 | 24.7 | 21.62 | 43.24 | 4.91 |
| .06610 | .0920 | 109.51 | 64.850 | 277 | 10.0 | 13.95 | 11.975 | 23.95 | 16.95 | 23.6 | 20.27 | 40.54 | 4.61 |
| .0840 | .1080 | 120.64 | 68.425 | 279.2 | 11.6 | 14.9 | 13.25 | 26.5 | 20.4 | 26.2 | 23.4 | 46.8 | 5.32 |
| .03005 | .06035 | 56.50 | 27.525 | 279.2 | 8.85 | 17.85 | 13.35 | 26.7 | 18.6 | 36.8 | 27.7 | 55.4 | 6.3 |
| .0363 | .06050 | 70.79 | 38.750 | 279.2 | 8.60 | 14.3 | 11.45 | 22.9 | 15.65 | 26.1 | 20.87 | 41.74 | 4.75 |
| .01185 | .03895 | 33.88 | 12.700 | 279.2 | 5.85 | 19.2 | 12.525 | 25.15 | 15.5 | 51.1 | 33.3 | 66.6 | 7.57 |

DATA SHEET Nº 7.

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## INDUCTION MOTOR TESTS.

All motors in this plant are of the three phase induction type, operating on 60 cycles and 220 volts between mains. They are used for various purposes, more than one being used for each purpose, and since all the motors for any one purpose are of the same size and type, only one of each group was tested. The brine circulator motors in the ice tanks were found to be very badly grounded, so that it was impossible to test them without lifting them off their frames, and removing the ground. This was impractical, however, inasmuch as they were needed all of the time, and could not be put out of service for a sufficient length of time to do this.

Method of Testing:-

The motors were tested in the following manner, because neither of the direct methods of stray power or prony brake, could be applied, it being impossible to vary the load directly, or to apply a prony brake. The circle diagram method was used; this is a theoretical method which has been found to agree quite closely with the other more reliable methods. It was carried out in the following manner. The apparatus was connected up as shown in the scheme, and the motor was run without any load and at full voltage, the following readings being taken:- Wattmeter, Voltmeter and Ammeter. The rotor was then blocked

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# DIAGRAM OF CONNECTIONS FOR MOTOR TESTS.

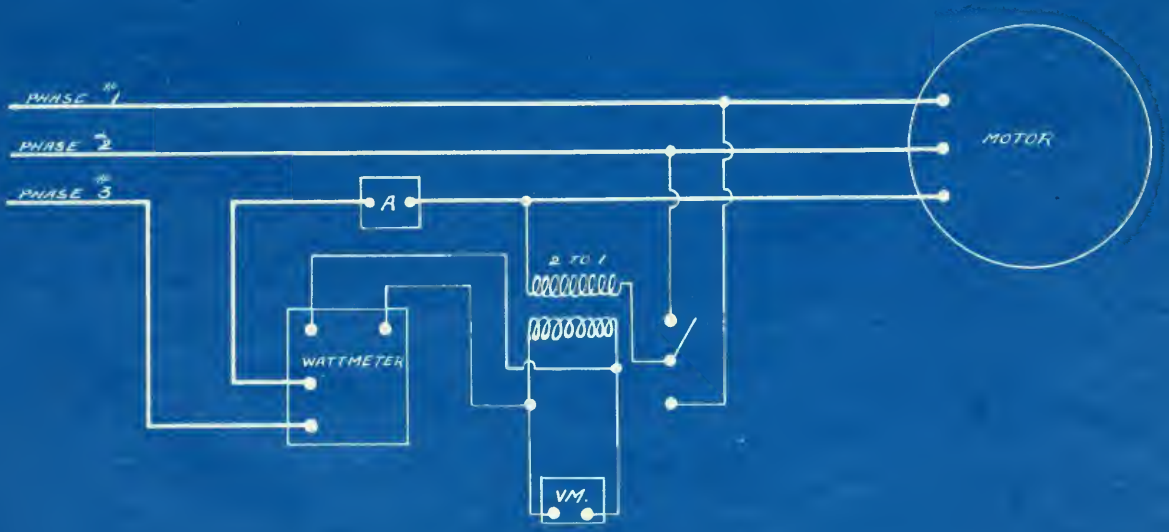


FIG. No 25

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and sufficient voltage was applied to send approximately full current through the motor. The same readings were taken as before. From this data the circle diagram was worked out in the following manner.

Fairbanks 5 H.P. Induction Motor.

Data.

$W_1$ = 1520. $W_2$ =-451 V = 220 A = 8.5

Part 2. Rotor blocked.

$W_1$ = 385 $W_2$ = 50 V = 35.75 A =11.75

Direct current measurement for resistance.

V = 1.98 I = 5.00

All the current and resistance quantities obtained were reduced to equivalent single phase quantities and used in the following manner.

Equivalent single phase magnetizing current.

8.5 x 1.73 = 14.7 amperes.

Power factor at no load

$$= \frac{1520 - 451}{1.73 \times 8.5 \times 220} = .33$$

Equivalent single phase current with rotor blocked.

11.75 x 1.73 = 20.3275 amperes.

This is the value with 35.75 volts applied. If full voltage were applied the current would be

$$\frac{11.75 \times 1.73 \times 220}{35.75} = 125 \text{ amperes.}$$

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The power factor of this current is equal to

$$\frac{385 \text{ plus } 50}{1.73 \times 11.75 \times 35.75} = .598$$

When the rotor is blocked all the energy is dissipated as copper loss, and therefore the total copper loss for this condition is equal to

$$\frac{220^2}{35.75^2} \times 436 = 16480 \text{ watts.}$$

The primary copper is equal to the square of the current, multiplied by one half of the resistance, between any two terminals as measured by direct current. This is the equivalent single phase resistance, and applies, regardless of whether the motor is star or delta connected.

The primary copper loss.

$$1.73 \times 11.75 \times \left(\frac{220}{35.75}\right)^2 \times \frac{.396}{2} = 3100 \text{ watts.}$$

The secondary copper loss is the difference between the total copper loss and the primary.

16480 - 3100 = 13380 watts.

The quantities were used in plotting the circle diagram in the following manner. All letters apply to the circle diagram of the Fairbanks-Morse 5 Horse-power induction motor.

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The magnetizing current is laid off from the point θ, at the proper angle determined by the power factor. The line OA represents in magnitude and direction the magnetizing current. MA is the power component of this current and AN the wattless component. From the point A the line AH is drawn parallel to the X axis. The distance between AH and the X axis represents iron and friction losses, and a small copper loss. From O the equivalent "blocked rotor" current is laid off at the angle determined by the power factor. The line joining A and C is the secondary current for the same condition. From the point C the line CH is drawn perpendicular to AC. The three points A, C and H lie on the circumference of a circle whose diameter equals AH. The line CE represents the total copper loss of the machine. It is divided at the point D in such a proportion that the part DE represents primary copper loss and CD represents secondary copper loss. Through A and D a line is drawn intersecting the circumference at G. Therefore, for any load, the portion between AG and AH represents primary copper loss to an arbitrary scale, and everything between AC and AG equals secondary copper loss to the same scale. The diagram is now used in the following manner in obtaining

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the efficiency, power factor, %slip and torque.

Sample Calculation:-

Taking the value 5 H.P.

$1.73\ EI \cos \phi = 5 \times 746.$

Let $I' = 1.73\ I$

$EI' \cos\phi = 5 \times 746.$

Let $I'' = I' \cos \phi$ = power component of current.

$EI'' = 3730.$

$I'' = 16.95$ amperes.

$1.73 \times 16.95 = 29.4$ amperes.

This value is laid off along a vertical from the horizontal line AH. VP then represents the power component of the current for 5 H.P. The total current is represented in amount and direction by the line OP. The power factor is found by producing PO until it crosses the power factor circle, and then projecting back horizontally from this point until it intersects the Y axis, where the power factor can be read directly.

OP = 34.8 amperes. Power factor = .845

The secondary current is represented by the line AP. The efficiency is equal to the ratio of output to input. PS is the output in watts and PW is the input. PS = 4910 watts. PW = 6890 watts.

$$\frac{4910}{6890} \times 100 = 71.5\ \%. = \text{Efficiency.}$$

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The slip, considering synchronism as unity, is equal to SI divided by PI. For 5 H.P. the slip is

$$\% \text{ slip} = 100 \times \frac{.1345}{1} = 13.45\%.$$

The torque in foot-pounds at one foot radius may be found from the equation

$$\text{Torque} = \frac{\text{Synchronous watts.}}{\text{Synchronous speed.}}$$

Synchronous watts are represented in the diagram by the line PT.

$$\text{Torque} = \frac{7.04 \times 5680}{1200}$$

$$= 33.3 \text{ foot-pounds.}$$

Conclusions:--

There are two of the Fairbanks-Morse 5 H.P. motors, both of which are used on the coal handling system. One is used to elevate the coal 30 feet to a conveyor, and the other drives the conveyor. Both of the motors are geared down, and the speed is further reduced by means of a belt pulley so as to drive the conveyor at a very low speed. The efficiency is about what can be expected of a 5 H.P. motor and the power factor is good. The motor is not operated continuously but when it is running, it is loaded to the limit so that at all times, it is operating to the best advantage. These motors

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are very small for their output, as compared with the Westinghouse motor of the same type.

The Westinghouse 5 H. P. motors of which there are two, are coupled directly to two centrifugal turbine pumps, which circulate brine through the ice storage houses. One of these motors is in use all of the time, and the other one is held in reserve, so that it can be used, if something should happen to the other. A spare motor of the same size and type is available for attaching to these pumps or for belting to an auxiliary air compressor.

The efficiency of the Westinghouse 5 H.P. motor is about the same as that of the 5 H.P. Fairbanks-Morse, although the latter is considerably smaller than the former. The Westinghouse motor could be rated considerably higher on the basis of equal heating, because it is located in a very cold place. Therefore, it can safely carry a higher overload than the Fairbanks-Morse motor can. The power factor of the Westinghouse motor is considerably lower than that of the Fairbanks at high loads, but at no load the power factor of the Westinghouse motor is smaller than that of the

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Fairbanks-Morse, which gives a considerably smaller iron and friction loss.

The small Westinghouse 1 H.P. motor is direct-connected to a $1\frac{1}{4}$" centrifugal pump which circulates the filtered water through the D-P cooling coils, storage tank and international filters. It is running continuously, very heavily loaded at all times. The motors tested were in good condition and operating very satisfactorily. All of the motors throughout the plant were not available for testing, due to the fact that they could not be disconnected from their load for any suffisient length of time, and the load could not be varied. Since the energy is not costing anything it would be useless to have motors of very high efficiency, and correspondingly great cost, and for the same reason the power factor is of very little consequence.

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# DATA FOR TEST OF
# FAIRBANKS MORRIS 5 HP. 3 ϕ 60~ 220 V
# INDUCTION MOTOR No. 14162.

| $W_1$ | $W_2$ | V | I | $W_1 + W_2$ | DIRECT CURRENT | |
|---|---|---|---|---|---|---|
| MOTOR RUNNING WITHOUT LOAD | | | | | E | I |
| 1520 | -451 | 220 | 8.5 | 1069 | 1.98 | 5 |
| ROTOR BLOCKED | | | | | R | R.P.M 1200 |
| 385 | 50 | 35.75 | 11.75 | 435 | .396 Ω | |

| HORSE POWER OUTPUT | CURRENT PER WIRE | EQUIVALENT SINGLE PHASE CURRENT $I/\sqrt{3}$ | POWER COMPONENT OF I' | POWER FACTOR | WATTS OUTPUT | WATTS INPUT | PERCENT EFFICIENCY | PERCENT SLIP | TORQUE IN SYNCHRONOUS WATTS. | TORQUE IN FT. LBS. |
|---|---|---|---|---|---|---|---|---|---|---|
| HP | I | I' | I'' | P.F | W. | $W_2$ | E | S | $W_s$ | T |
| 0 | 8.5 | 14.7 | 4.8 | .33 | 0 | 1130 | 0 | 0 | 0 | 0 |
| 1 | 8.78 | 15.2 | 5.88 | .385 | 196.5 | 1380 | 14.2 | .5 | 215 | 1.26 |
| 1.5 | 10.72 | 18.6 | 8.83 | .53 | 885 | 2100 | 42. | 2.78 | 980 | 5.31 |
| 2.175 | 11.2 | 19.4 | 12.75 | .66 | 1820 | 3000 | 60.7 | 5.25 | 1820 | 10.7 |
| 3 | 13.5 | 23.4 | 17.6 | .75 | 2850 | 4200 | 68.7 | 7.2 | 3005 | 17.65 |
| 4 | 16.62 | 28.8 | 23.9 | .815 | 3980 | 5600 | 71.0 | 10.0 | 4310 | 25.3 |
| 5 | 20.05 | 34.8 | 29.4 | .845 | 4910 | 6890 | 71.5 | 13.45 | 5680 | 33.3 |
| 6 | 23.75 | 41.1 | 35.28 | .86 | 5820 | 8400 | 69.3 | 16.0 | 6950 | 40.75 |

DATA SHEET No 8.

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# DATA FOR TEST OF
# WESTINGHOUSE 1 H.P. 3 Ø 60~ 220 V.
# INDUCTION MOTOR N° 379361

| $W_1$ | $W_2$ | $V$ | $I$ | $W_1 + W_2$ | DIRECT CURRENT | |
|---|---|---|---|---|---|---|
| MOTOR RUNNING WITHOUT LOAD | | | | | $E$ | $I$ |
| 680 | -390 | 220 | 4.45 | 290 | | |
| ROTOR BLOCKED | | | | | $R$ | R.P.M 1800 |
| 210 | 60 | 59. | 4.6 | 270 | | |

| HORSE POWER OUTPUT | CURRENT PER WIRE | EQUIVALENT SINGLE PHASE CURRENT $I/\sqrt{3}$ | POWER COMPONENT OF $I'$ | POWER FACTOR | WATTS OUTPUT | WATTS INPUT | PERCENT EFFICIENCY | PERCENT SLIP | TORQUE IN SYNCHRONOUS WATTS | TORQUE IN FT. LBS |
|---|---|---|---|---|---|---|---|---|---|---|
| H.P | $I$ | $I'$ | $I''$ | P.F. | $W_1$ | $W_2$ | $E$ | S | $W_6$ | $T$ |
| 0 | 4.47 | 7.7 | 1.4 | .171 | 0 | 360 | 0 | 0 | 0 | 0 |
| 1/4 | 4.74 | 8.2 | 1.47 | .355 | 336 | 696 | 48.3 | .6 | 360 | 1.4 |
| 1/2 | 5.25 | 9.1 | 2.93 | .465 | 649 | 1060 | 61 | 4.9 | 696 | 2.72 |
| 3/4 | 6.78 | 10. | 4.4 | .58 | 912 | 1390 | 65.6 | 11.6 | 1032 | 4.03 |
| 1 | 6.62 | 11.3 | 5.87 | .64 | 1150 | 1750 | 65.7 | 16.8 | 1390 | 5.44 |
| 1 1/4 | 7.4 | 12.8 | 7.35 | .68 | 1320 | 2090 | 63.3 | 19.6 | 1658 | 6.47 |

DATA SHEET No 9.

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# DATA FOR TEST OF WESTINGHOUSE 5 HP 3 Ø 60~ 220 V INDUCTION MOTOR No 265088

| $W_1$ | $W_2$ | V | I | $W_1 + W_2$ | DIRECT CURRENT | |
|---|---|---|---|---|---|---|
| MOTOR RUNNING WITHOUT LOAD | | | | | E | I |
| 940 | -77 | 220 | 7.82 | 077 | 1.92 | 2.75 |
| ROTOR BLOCKED | | | | | R | R.P.M. 1200 |
| 580 | -35 | 44 | 12.86 | 545 | .698 Ω | |

| HORSE POWER OUTPUT | CURRENT PER WIRE | EQUIVALENT SINGLE PHASE CURRENT $I/\sqrt{3}$ | POWER COMPONENT OF I' | POWER FACTOR | WATTS OUTPUT | WATTS INPUT | PERCENT EFFICIENCY | PERCENT SLIP | TORQUE IN SYNCHRONOUS WATTS | TORQUE IN FT. LBS. |
|---|---|---|---|---|---|---|---|---|---|---|
| H.P. | I | I' | I'' | P.F. | $W_1$ | $W_2$ | E | S | $W_s$ | T |
| 0 | 7.82 | 13.55 | 3.8 | .293 | 0 | 836 | 0 | 0 | 0 | 0 |
| 1 | 8.32 | 14.40 | 5.88 | .43 | 462. | 1300 | 35.6 | 1 | 505 | 2.99 |
| 1.5 | 8.74 | 15.10 | 8.83 | .585 | 1055 | 2160 | 49 | 4 | 1100 | 6.45 |
| 2.0 | 9.36 | 16.20 | 11.8 | .69 | 1670 | 2600 | 64.3 | 5 | 1760 | 10.31 |
| 3 | 11.90 | 20.6 | 17.6 | .79 | 2820 | 3920 | 72 | 5.66 | 2990 | 17.5 |
| 4 | 13.45 | 23.3 | 23.9 | .835 | 3780 | 5150 | 73.4 | 8.5 | 4140 | 24.2 |
| 5 | 16.80 | 29.1 | 29.4 | .84 | 4670 | 6430 | 72 | 11.6 | 5280 | 30.9 |
| 6 | 20.40 | 35.4 | 35.28 | .845 | 5500 | 7750 | 71. | 14.3 | 6440 | 37.7 |

DATA SHEET No 10.

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## BOILER TESTS.

The object of these tests was to determine the efficiency of the boilers and the cost of evaporation.

The apparatus used during the tests was located in the following places.

Thermometers:-- The thermometer for measuring the temperature of the outside air was hung outside of one of the boiler room windows, where it was sheltered from the winds. That one for measuring the temperature in the boiler room was located on a nail in a place free from all drafts. That for measuring the temperature of the feed water was located in the discharge line from the pump. The temperature of the flue gas was obtained by a thermometer placed in the flue between the boiler and the damper.

Quality of the steam:-- This was determined by means of a throttling calorimeter placed directly on the boiler and therefore steam was obtained from the boiler direct, without passing through a separator. The thermometer in the calorimeter was immersed in cylinder oil.

Water-- The water used during a test was measured by means of an Empire hot-water meter, which was calibrated before the test. The meter being

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placed directly in the feed water line between the pump and the boiler tested, only the water going into the one boiler was measured.

Coal:-- The coal was weighed in a barrel and dumped directly into the hopper of the boiler under test. The sample of coal used for our analysis was obtained by taking a shovelful out of every second barrel of coal used, and at the end of the test, all these samples were quartered down, and a quart jar of the coal was taken as the average. This was sealed tightly to prevent escape of moisture and maintained this way until it was analyzed.

Flue:-- The flue gas was analyzed every thirty minutes for carbon dioxide and oxygen, the sample being obtained from the flue between the boiler and breeching, by means of a sampling tube which extended about 4" into the flue. This sampling tube consited of a thin piece of .75" iron tubing, with a large number of .125" holes drilled in it; the Orsat apparatus was used.

Draft:-- The draft was obtained at the same place that the gas sample was taken from, by means of an Ellison inclined draft gauge reading directly to .1 inches of water.

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The results were calculated in the following manner. These given below are for Boiler #3.

Grate surface = 5' x 8' = 40 sq. '

Heating surface.

Length of boiler = 20'.

Number of tubes = 72.

Diameter (boiler) = 72"

Diameter ( tubes) = 4"

Heating surface is equal to the total inside area of the tubes plus .66 of the cylindrical area of the shell plus .66 of the end area of the boiler minus .66 x 3 of the end area of the tubes.

Length of tubes, per square foot of inside area = 1.024' (Taken from table in Kent's Handbook).

$\frac{20}{1.024}$ = 19.5 square feet per tube.

72 x 19.5 = 1406 " " of heating surface of the tubes.

$\frac{72 \times 80.3}{4 \times 144}$ = 8.27 " " of end area.

.66 x 3.14 x 8 x 20 = 251.4 sq.' of shell surface.

2 x .66 x 3.14 x 9 - 8.27 = 25.4 square feet of useful tube sheet area.

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Total heating surface.

1406 plus 251.4 plus 25.4 = 1682.9 sq.'

Ratio of heating surface to grate surface is equal to

$$\frac{1682.9}{40} = 42.08$$

The average temperatures were as follows:

| | |
|---|---|
| External air | 20.5 F. |
| Boiler Room | 75.5 |
| Steam in Calorimeter | 256.6 |
| Feed water | 198.5 |
| Flue Gas | 590.4 |

The average pressures were as follows:-

| | |
|---|---|
| Steam | 119.0 |
| Draft | .4215" $H_2O$. |

FUEL.

The coal used during this test was a fairly good grade of Illinois screening, containing a high percentage of ash and moisture. The latter was considerably increased over its normal value, due to the fact that it rained very hard, the night before the test, and the coal was lying out in it. When analysing the coal, two samples were used and the average of the two results brought into the calculations which follow:-

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| | | |
|---|---|---|
| Weight of coal as fired | 8356# | |
| % Moisture by analysis | | 15.275 |
| Total weight of dry coal (100 - 15.275) 8356 | 7080# | |
| Total weight of ash and refuse | 1376# | |
| Total combustible consumed (7080) - (1376) | 5703# | |
| % ash in dry coal $\frac{8356}{7080} \times 11.35$ | | 13.55 |
| % ash as fired | | 11.35 |

Proximate analysis of coal.

| | |
|---|---|
| Fixed Carbon | 43.96 |
| Volatile Matter | 29.315 |
| Moisture | 15.275 |
| Ash | 11.35 |

Fuel consumed per hour.

| | | |
|---|---|---|
| Dry coal consumed per hour | $\frac{7080}{8}$ | 885# |
| Combustible consumed per hour | $\frac{5703}{8}$ | 713# |
| Dry coal per hour per square foot of grate surface | $\frac{7080}{40 \times 8}$ | 21# |
| Combustible per hour per square foot of heating surface | $\frac{5703}{1662.9 \times 8.0}$ | .424# |

Calorific Value of Fuel.

The heating value of the fuel was determined by means of a Parr Calorimeter. The following

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| | B.T.U. |
|---|---|
| results were obtained for this boiler. | |
| Calorific value per pound of coal as fired | 10200 |
| Calorific Value per pound of combustible $\frac{10200}{1.0 - (.15275 \text{ plus } .1135)}$ | 13900 |
| Calorific value per pound of dry coal $\frac{10200}{1.00 - .15275}$ | 12050 |

Quality of Steam.

The quality of the steam was determined from the data in the following manner.

$$X = \frac{H - Q \text{ plus } .48 (T - 212)}{L}$$

H = Total heat of the liquid at steam pressure.

L = Latent heat of the liquid at steam pressure.

Q = Heat of the liquid at atmospheric pressure.

It is assumed that the pressure in the calorimeters is the same as that of the atmosphere. This is not actually the case but usually close enough for all practical purposes. The boiling point is also a little different than 212 under the conditions, but the error is so slight that it is negligible.

X = 97.61 % = Quality.

(100 - 97.61) = 2.39% moisture in steam.

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## Water.

| | |
|---|---|
| Total weight of water | 49450# |
| Factor of Evaporation | 1.0575 |
| Equivalent water at 212 | |
| 49450 x 1.0575 | 52200# |
| Water actually evaporated, corrected | |
| for quality 49450 x .9761 | 48200# |
| Equivalent water evaporated from | |
| and at 212 48200 x 1.0575 | 50955# |

## Water Evaporated per Hour.

| | |
|---|---|
| Water evaporated per hour, corrected | |
| for quality 48200 ÷ 8 | 6030# |
| Equivalent water evaporated per hour | |
| 50955 ÷ 8. | 6360# |
| Equivalent water evaporated per hour | |
| per sq.' of heating surface $\frac{6360}{1682.9}$ | 3.78# |

## Horse - Power.

Horse-power developed.

34.5# of water per hour = 1 H.P.

$\frac{6360}{}$ ÷ 34.5 = 184.5 H.P.

Builders' Rated Horse-power = 200.

% of Builders obtained = $\frac{184.5}{200}$ = 92.25 %

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## Economic Results.

Water evaporated per pound of coal as fired, 49460 ÷ 8356 = 5.9#

Equivalent evaporation per pound of coal as fired, 50955 ÷ 8356 = 6.1#

Equivalent evaporation per pound of dry coal, 50955 ÷ 7080 = 7.2#

Equivalent evaporation per pound of combustible, 50955 ÷ 5703 = 8.92#

## EFFICIENCY.

$$\text{Efficiency of boiler} = \frac{\text{Heat absorbed per lb. of combust.}}{\text{Cal. value per lb. of combustible.}}$$

$$= \frac{8.92 \times 965.7}{13900} = 62\%.$$

$$\text{Efficiency of boiler and grate} = \frac{\text{Heat absorbed per pound of coal}}{\text{Calorific value per lb. of coal.}}$$

$$= \frac{6.1 \times 965.7}{10200} = 57.8\ \%.$$

## Cost of Evaporation.

Cost of coal per ton $1.35

Cost of coal per pound 135 ÷ 2000 .0675¢

1000 ÷ 59 = 169# of coal needed to evaporate 1000# of water under actual conditions.

169 x .0675 = ¢.1144 per thousand pounds.

1000 ÷ 61 = 164# of coal required for equivalent evaporation of 1000# of water.

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164 x .0675 = $.1109 per thousand pounds.

Flue Gas Analysis.

| | | |
|---|---|---|
| Carbon Dioxide | = | 1.9% |
| Oxygen | = | 3.6% |

COST.

The cost of evaporating water under actual conditions is 11.28¢ per thousand pounds of water. This represents merely the cost of coal used. In addition to this there is a certain fixed charge attached to the boiler room cost, namely the salary of firemen and coal unloaders. The latter are generally helpers around the plant, and their salary cannot be charged entirely to boiler room maintainance, so it will be considered under the general fixed charges of the plant. The firemen are paid $2.50 for 8 hours work, and there is one man on duty each shift, bringing the total salary of the firemen up to $7.50, for twenty-four hours.

CONCLUSIONS.

The boilers were found to be operating very satisfactorily, the efficiency being about the average obtained for that type of boilers and the evaporation per pound of combustible consumed is high for that type.

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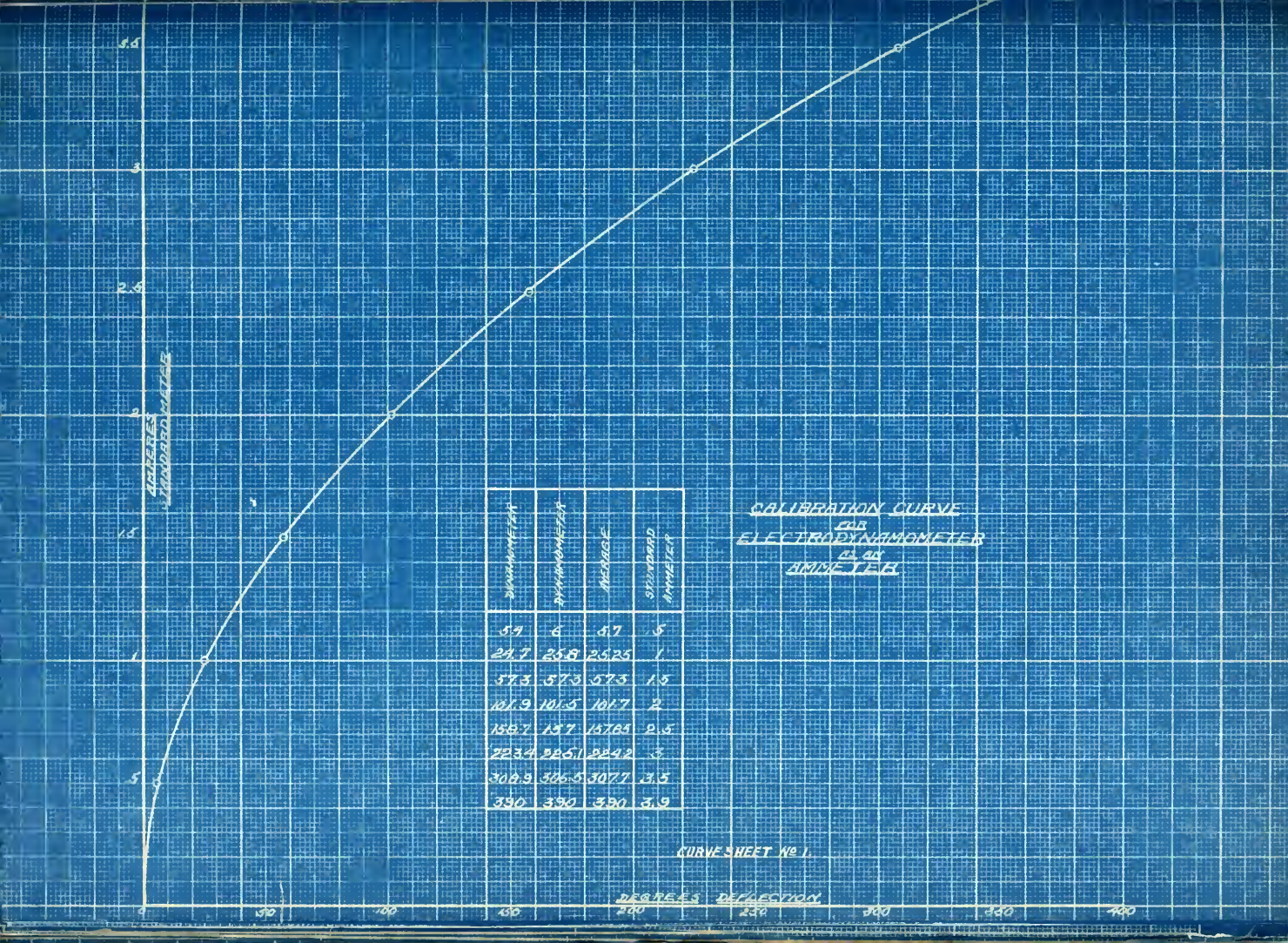


| AMMETER | AMMETER | MEAN | STANDARD AMMETER |
|---|---|---|---|
| 5.9 | 6 | 5.7 | .5 |
| 24.7 | 26.8 | 2.525 | 1 |
| 57.3 | 57.3 | 57.3 | 1.5 |
| 101.9 | 101.5 | 101.7 | 2 |
| 158.7 | 157 | 157.84 | 2.5 |
| 223.4 | 225.1 | 224.2 | 3 |
| 308.9 | 306.5 | 307.7 | 3.5 |
| 390 | 390 | 390 | 3.9 |

CALIBRATION CURVE
FOR
ELECTRODYNAMOMETER
&
AMMETER

CURVE SHEET No 1.

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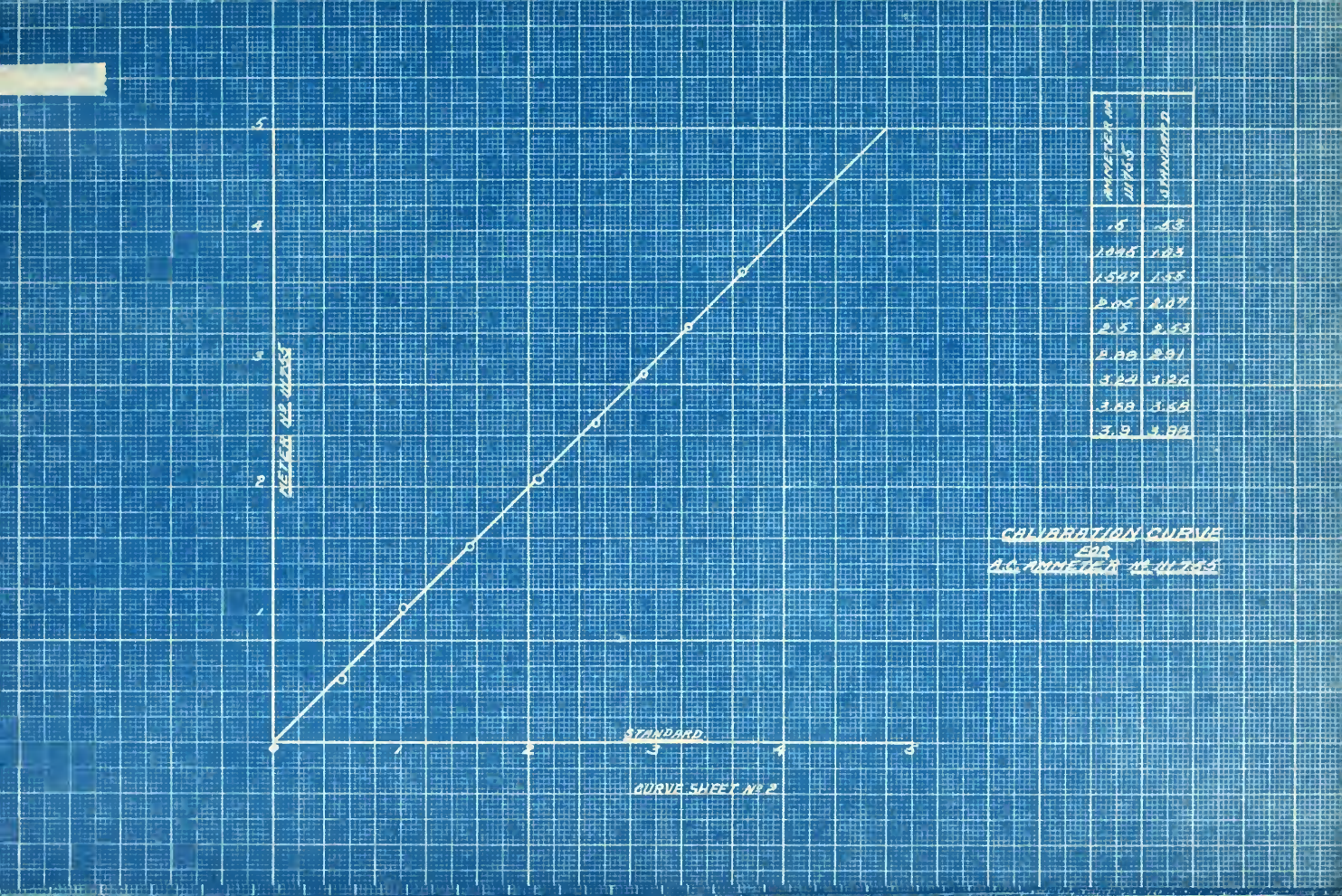

CALIBRATION CURVE
FOR
A.C. AMMETER No. 111755
AMMETER No. 111755
STANDARD
.5 .53
1.045 1.03
1.547 1.55
2.05 2.07
2.5 2.53
2.88 2.91
3.24 3.26
3.68 3.68
3.9 3.88
METER No. 111755
STANDARD
CURVE SHEET No. 2

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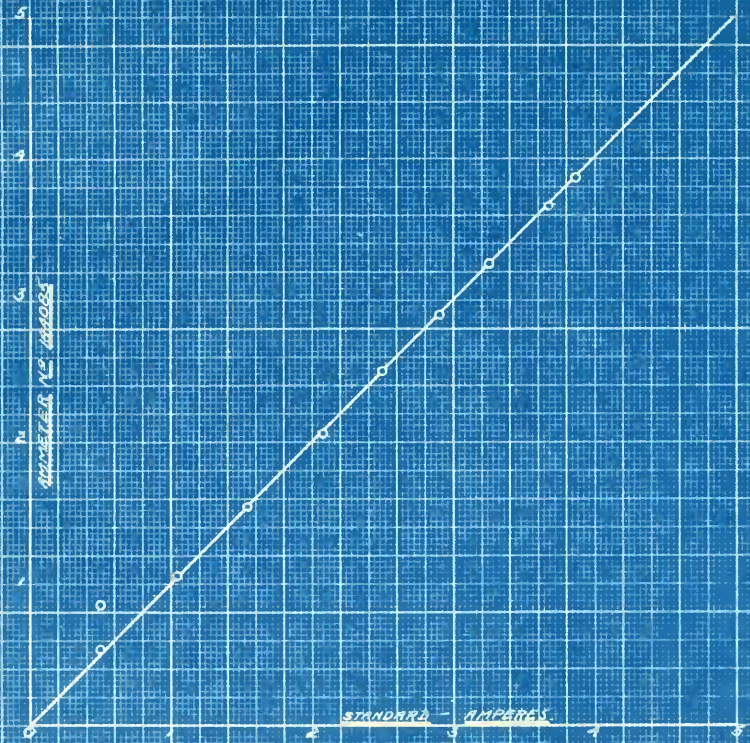


| AMMETER AC 144085 | STANDARD |
|---|---|
| .91 | .5 |
| 1.06 | 1.03 |
| 1.409 | 1.45 |
| 2.05 | 2.07 |
| 2.515 | 2.53 |
| 2.865 | 2.91 |
| 3.25 | 3.26 |
| 3.675 | 3.68 |
| 3.875 | 3.88 |

CALIBRATION CURVE
FOR
AC AMMETER No 144085

CURVE SHEET No 93

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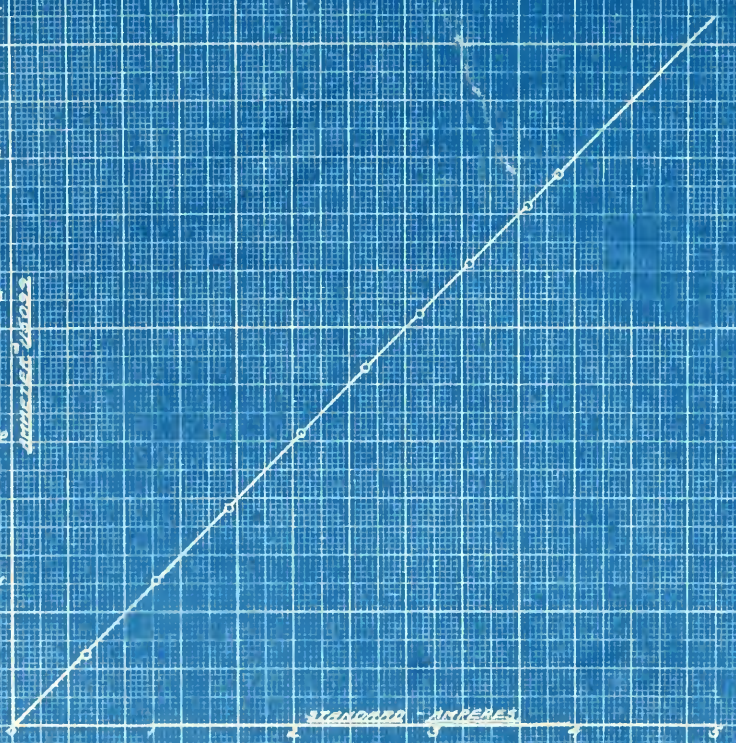


| AMMETER READING | STANDARD |
|---|---|
| .5 | .43 |
| 1.02 | 1.03 |
| 1.535 | 1.55 |
| 2.045 | 2.07 |
| 2.52 | 2.53 |
| 2.88 | 2.91 |
| 3.25 | 3.26 |
| 3.55 | 3.58 |
| 3.88 | 3.90 |

CALIBRATION CURVE
FOR
DC. AMMETER NO 115089

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| STANDARD | | | WATTMETER | | |
|---|---|---|---|---|---|
| VOLTS | AMPERES | WATTS | RIGHT | LEFT | AVERAGE |
| 100.2 | 1 | 100.2 | 89 | 109 | 99 |
| 100.2 | 2 | 200.4 | 206 | 188 | 197 |
| 100.2 | 3 | 300.6 | 288 | 304 | 296 |
| 100.2 | 4 | 400.8 | 400 | 388 | 394 |
| 100.2 | 5 | 501 | 484 | 501 | 492.5 |
| 100.2 | 6 | 601.2 | 596 | 579 | 587.5 |
| 100.2 | 7 | 701.4 | 675 | 691 | 683 |

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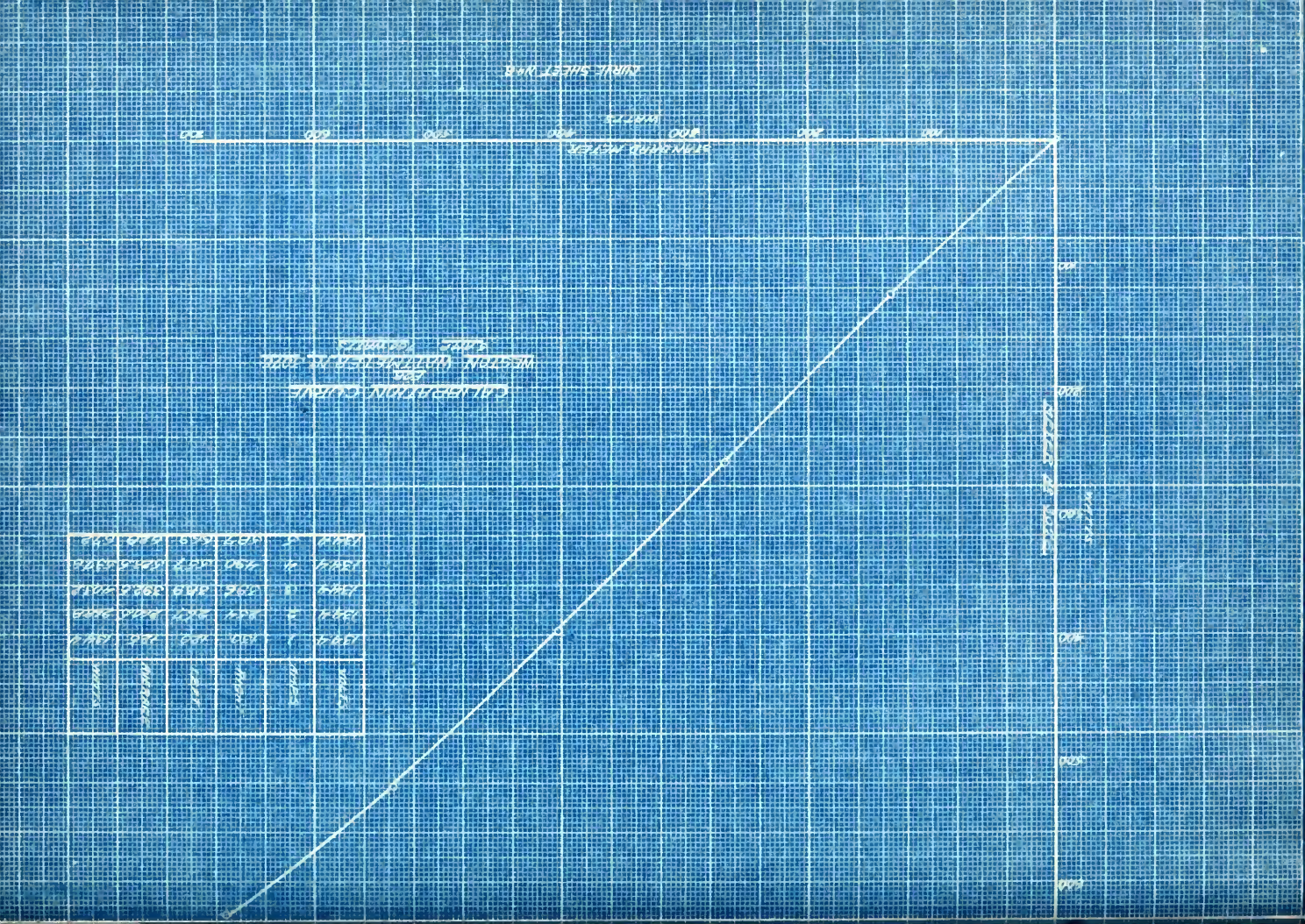

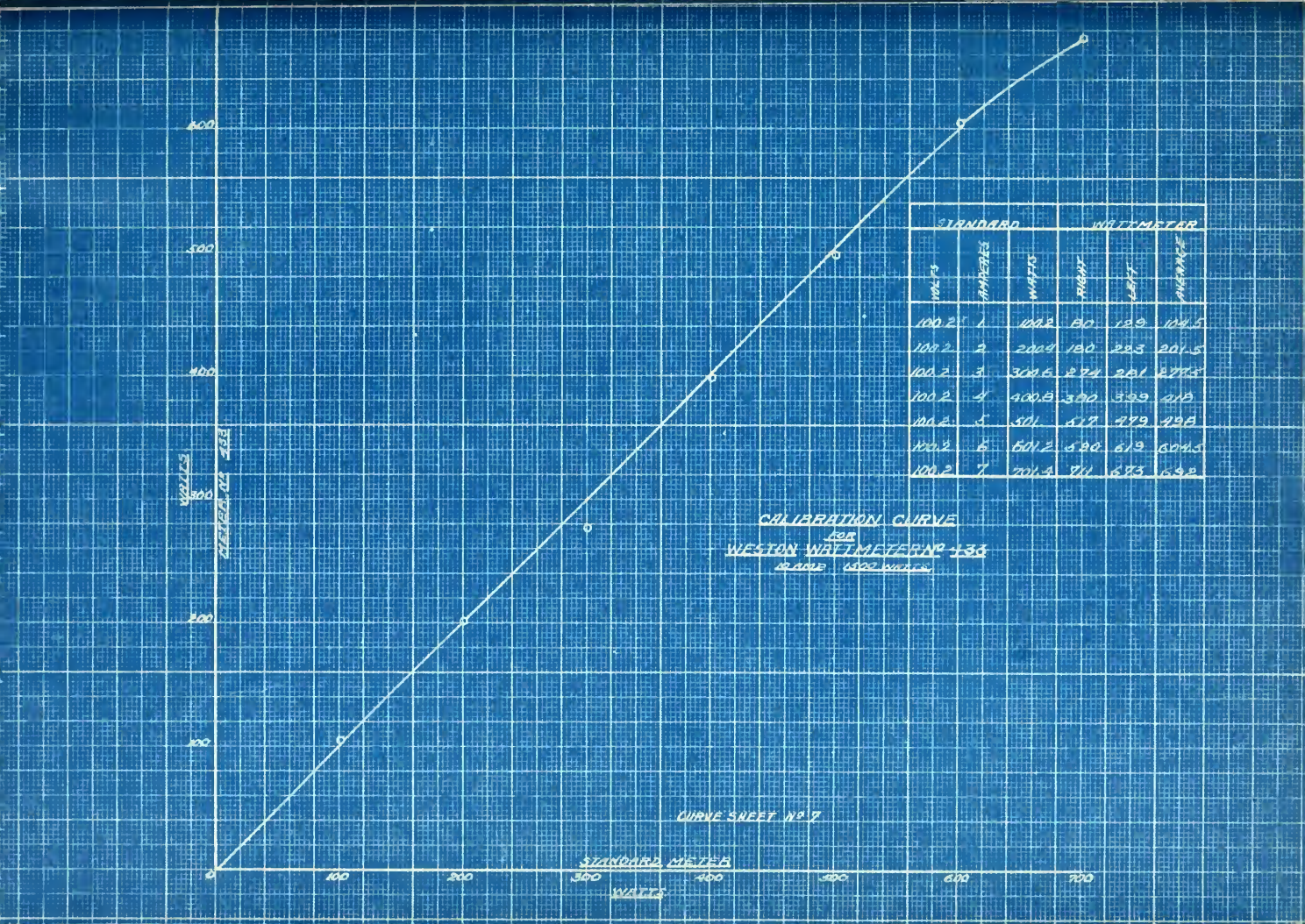


| STANDARD | | | WATTMETER | | |
|---|---|---|---|---|---|
| VOLTS | AMPERES | WATTS | RIGHT | LEFT | AVERAGE |
| 100.2 | 1 | 100.2 | 80 | 129 | 104.5 |
| 100.2 | 2 | 200.4 | 180 | 223 | 201.5 |
| 100.2 | 3 | 300.6 | 274 | 281 | 277.5 |
| 100.2 | 4 | 400.8 | 380 | 399 | 418 |
| 100.2 | 5 | 501 | 517 | 479 | 498 |
| 100.2 | 6 | 601.2 | 590 | 619 | 604.5 |
| 100.2 | 7 | 701.4 | 711 | 673 | 692 |

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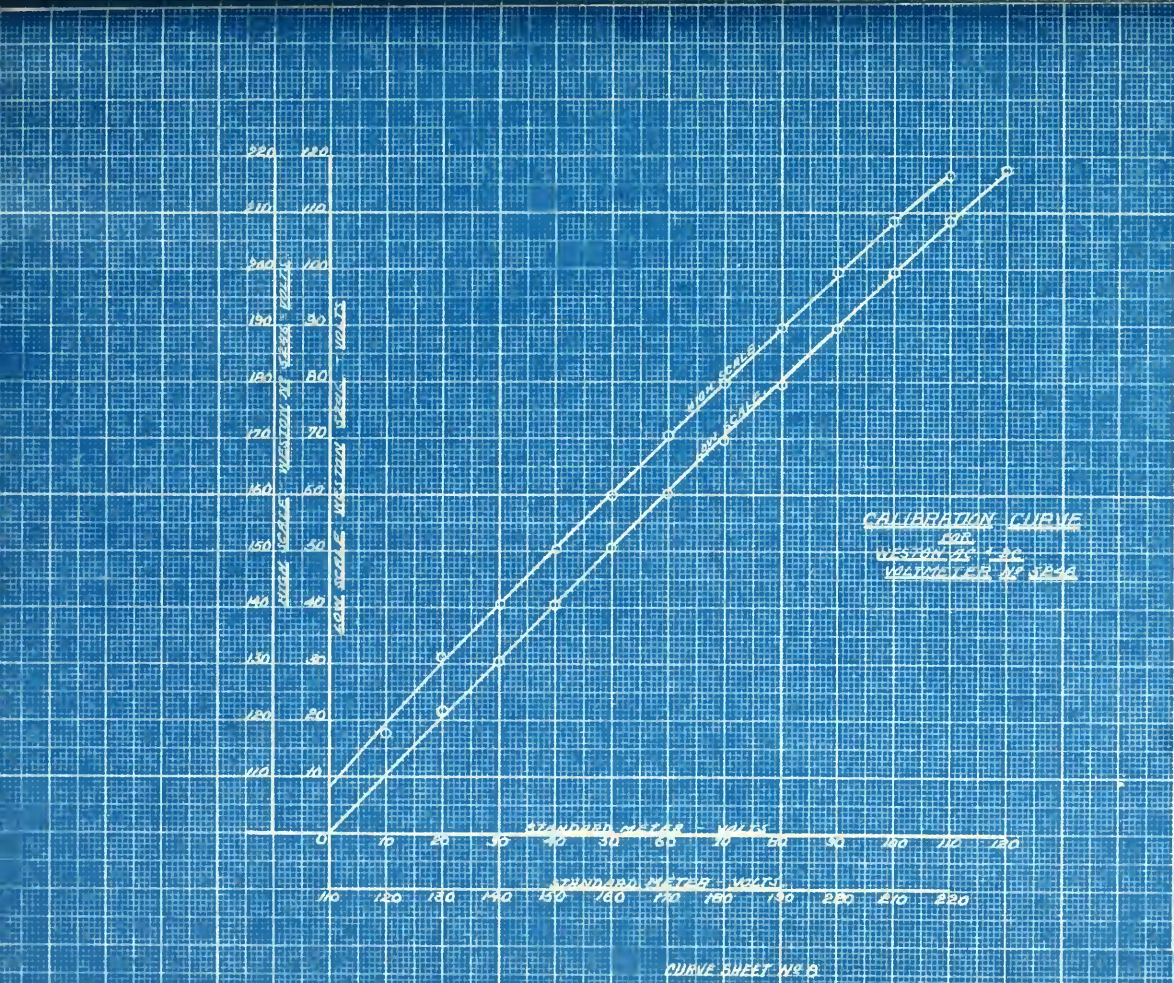


| Weston | Left | Average | Standard |
|---|---|---|---|
| 22 | 21.8 | 21.9 | 20 |
| 30 | 31 | 30.5 | 30 |
| 40 | 41 | 40.5 | 40 |
| 49.9 | 51 | 50.5 | 50 |
| 60.5 | 59.8 | 60.05 | 60 |
| 69.3 | 69.2 | 69.25 | 70 |
| 79.8 | 79.2 | 79.5 | 80 |
| 89.5 | 89.8 | 89.65 | 90 |
| 99.5 | 98.9 | 99.1 | 100 |
| 108.7 | 108 | 108.35 | 110 |
| 119.5 | 119 | 119.25 | 120 |
| 129.8 | 130.5 | 129.7 | 130 |
| 140.2 | 141 | 140.6 | 140 |
| 150 | 149.9 | 150.5 | 150 |
| 159.5 | 160.5 | 159.9 | 160 |
| 170.5 | 169.9 | 170.2 | 170 |
| 179.9 | 179.5 | 179.7 | 180 |
| 189.5 | 189.8 | 189.65 | 190 |
| 199.9 | 199.8 | 199.5 | 200 |
| 209.2 | 209.8 | 209.5 | 210 |
| 219.5 | 219.5 | 219.5 | 220 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
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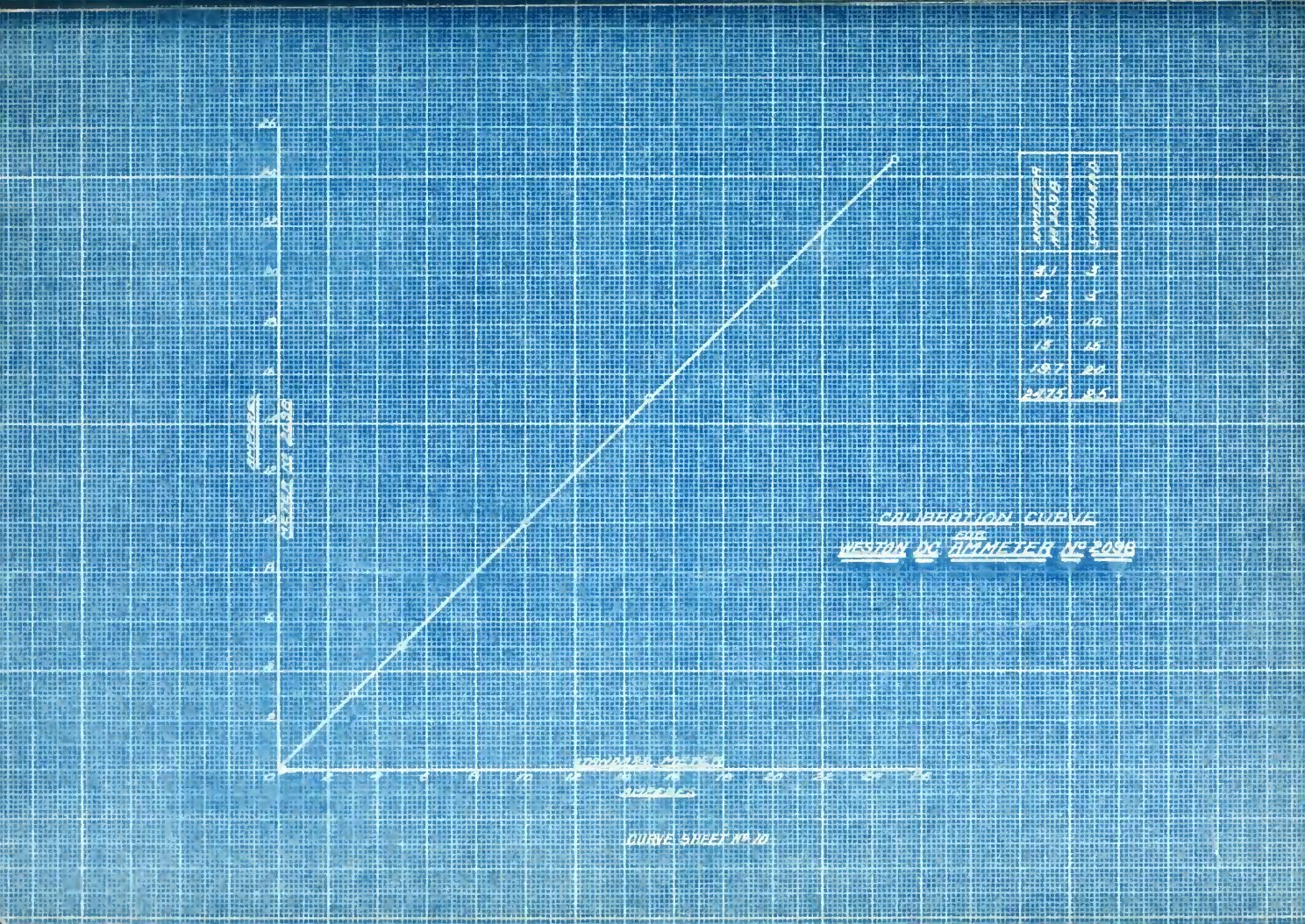
CALIBRATION CURVE
FOR
WESTON DC AMMETER No 2038
CURVE SHEET No 10

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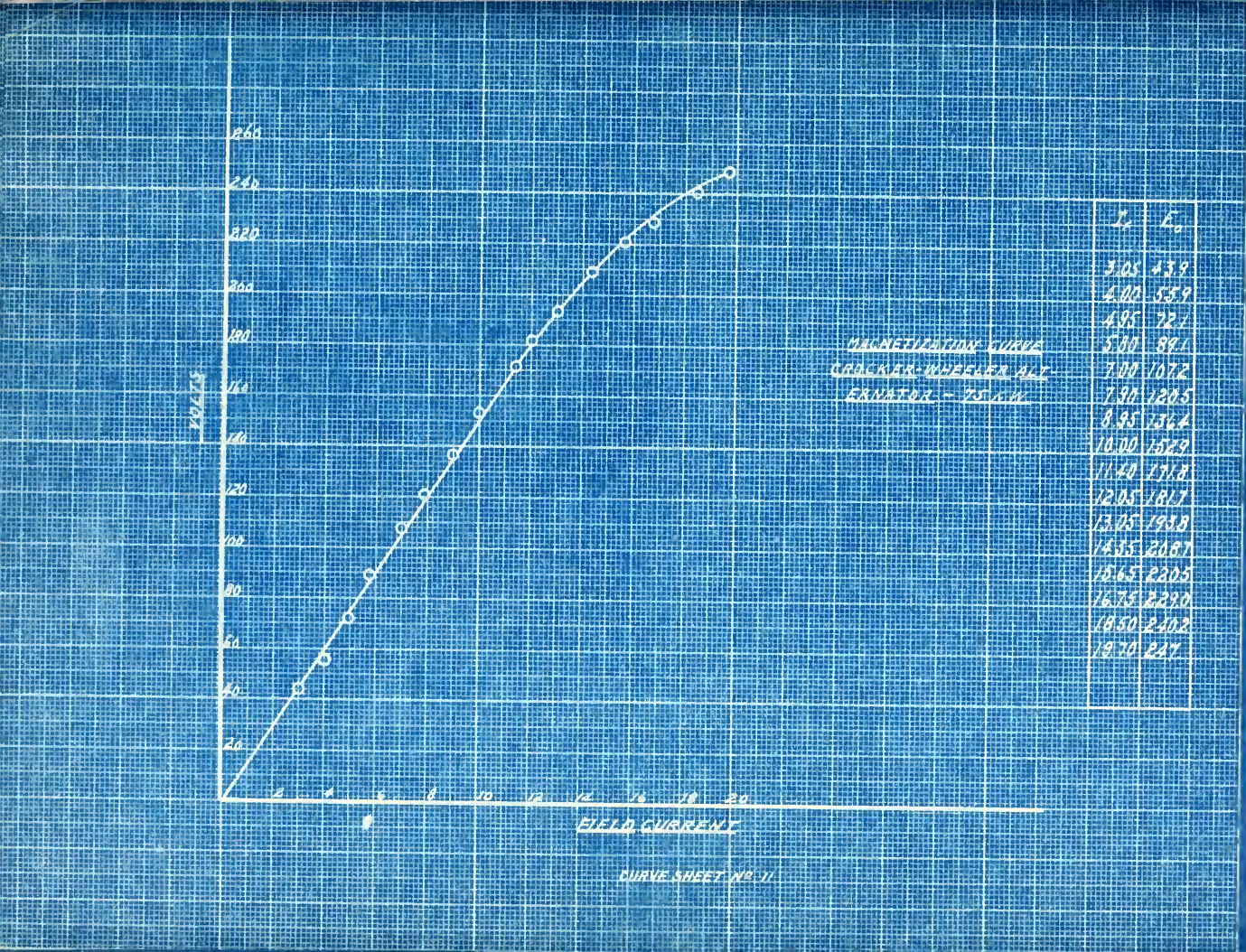


| $I_e$ | $E_o$ |
|---|---|
| 3.05 | 43.9 |
| 4.00 | 55.9 |
| 4.95 | 72.1 |
| 5.80 | 89.1 |
| 7.00 | 107.2 |
| 7.90 | 120.5 |
| 8.95 | 136.4 |
| 10.00 | 152.9 |
| 11.40 | 171.8 |
| 12.05 | 181.7 |
| 13.05 | 193.8 |
| 14.55 | 208.7 |
| 15.65 | 220.5 |
| 16.75 | 229.0 |
| 18.50 | 240.2 |
| 19.70 | 247 |

CURVE SHEET No. 11

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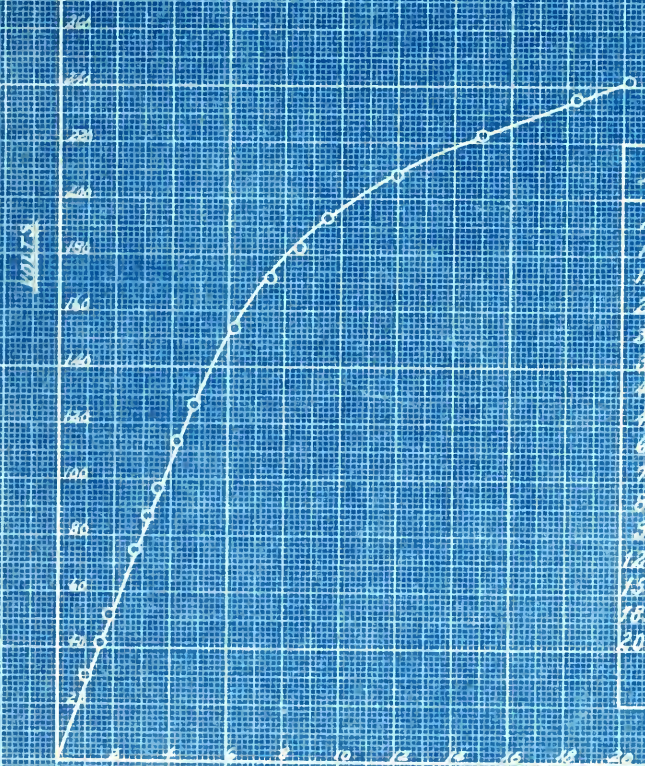


| $I_F$ | $E_0$ |
|---|---|
| 1.0 | 30.0 |
| 1.5 | 41.9 |
| 1.85 | 51.9 |
| 2.75 | 75.2 |
| 3.20 | 87.1 |
| 3.55 | 97.1 |
| 4.25 | 114.0 |
| 4.85 | 126.7 |
| 6.26 | 153.8 |
| 7.50 | 171.7 |
| 8.50 | 182.6 |
| 9.55 | 194.4 |
| 12.00 | 208.7 |
| 15.00 | 222.4 |
| 18.30 | 235.8 |
| 20.20 | 242.0 |

MAGNETIZATION CURVE
3 PHASE - 75 K.W. - 60 ~ - 240 VOLTS
BULLOCK ALTERNATOR

CURVE SHEET No. 12

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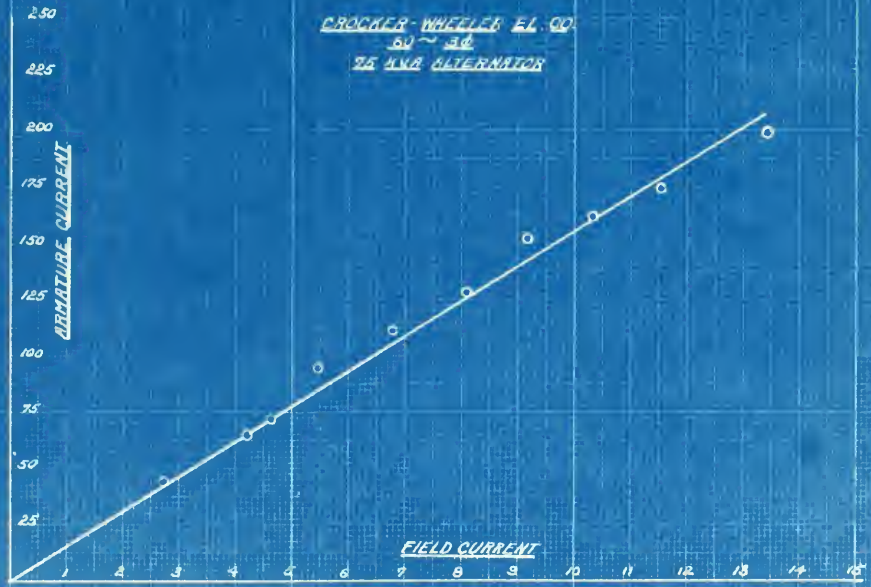


CURVE SHEET No 13

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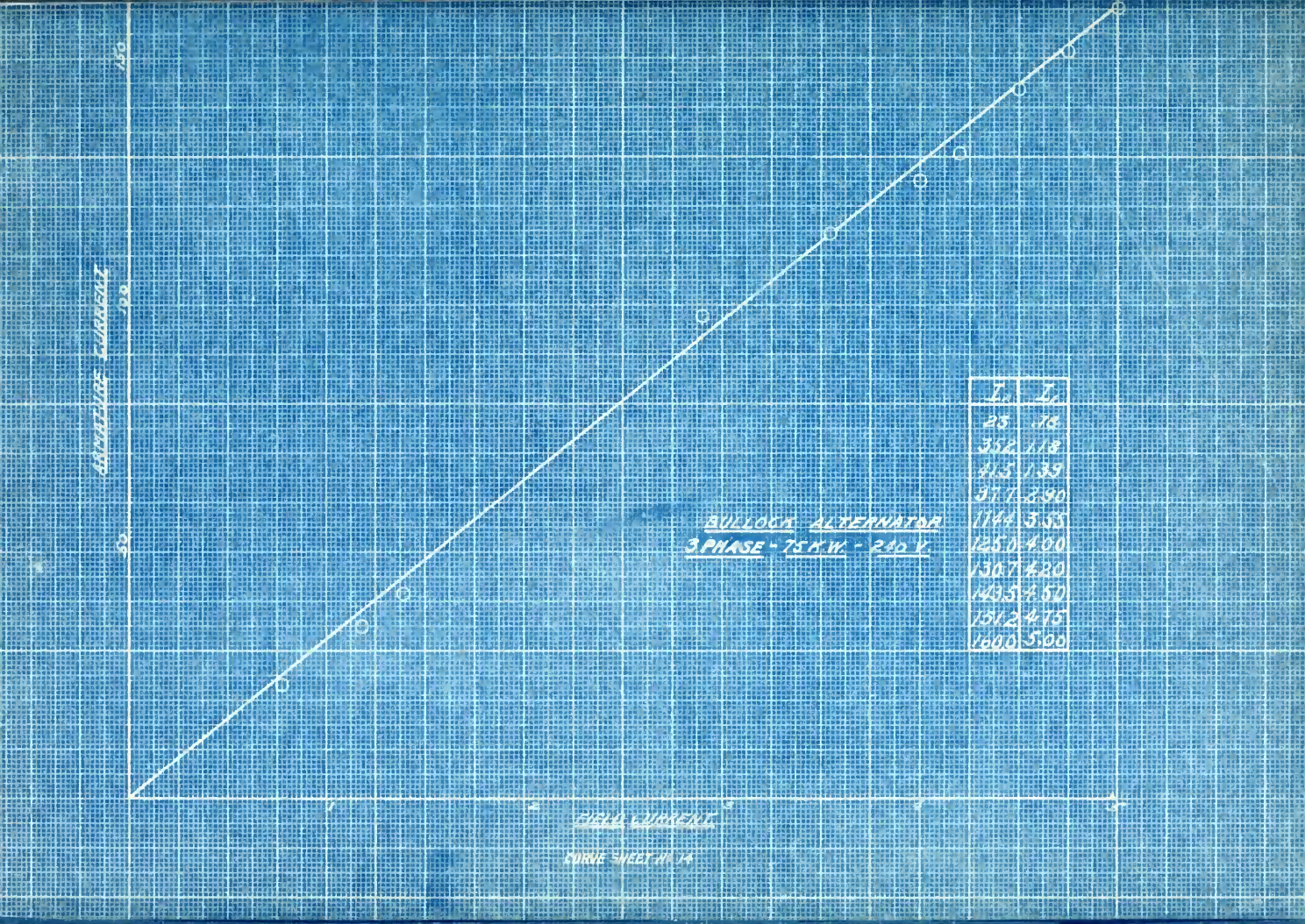


| $E_f$ | $E_a$ |
|---|---|
| 25 | 176 |
| 35.2 | 218 |
| 41.5 | 239 |
| 51 | 290 |
| 114 | 353 |
| 125 | 400 |
| 130 | 420 |
| 149.5 | 450 |
| 154.2 | 475 |
| 160.0 | 500 |

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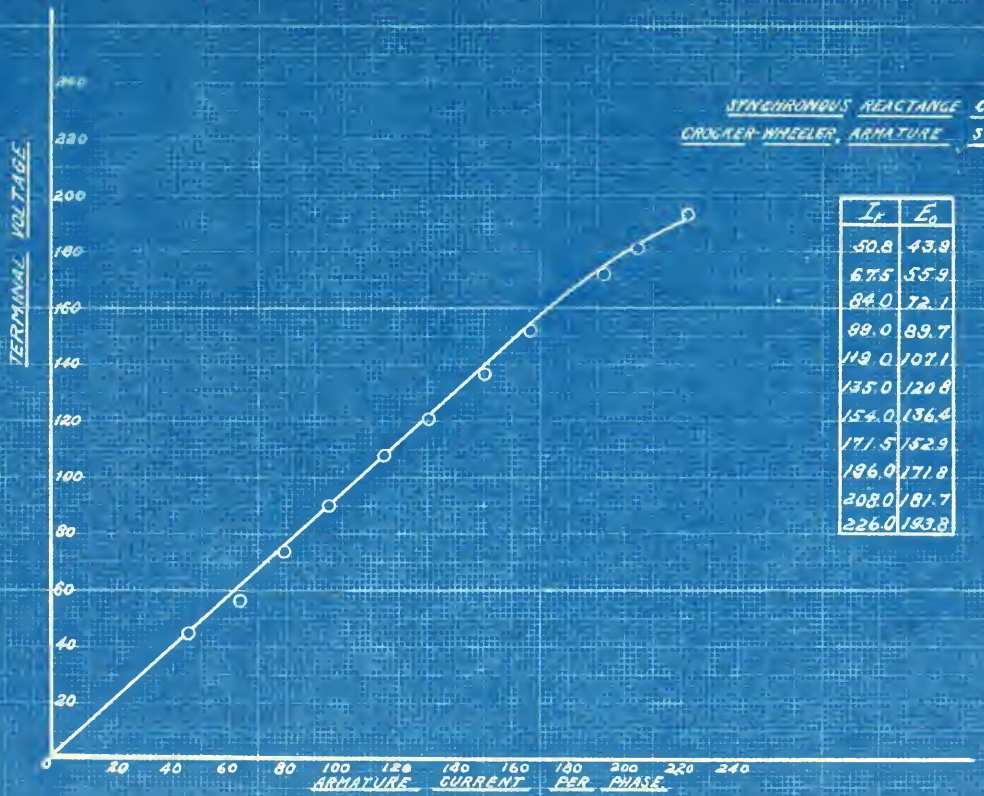
# SYNCHRONOUS REACTANCE CURVE

CROCKER-WHEELER, ARMATURE STAR CONNECTED.




| $I_f$ | $E_0$ |
|---|---|
| 50.8 | 43.9 |
| 67.5 | 55.9 |
| 84.0 | 72.1 |
| 98.0 | 89.7 |
| 119.0 | 107.1 |
| 135.0 | 120.8 |
| 154.0 | 136.4 |
| 171.5 | 152.9 |
| 196.0 | 171.8 |
| 208.0 | 181.7 |
| 226.0 | 193.8 |

CURVE SHEET Nº 15

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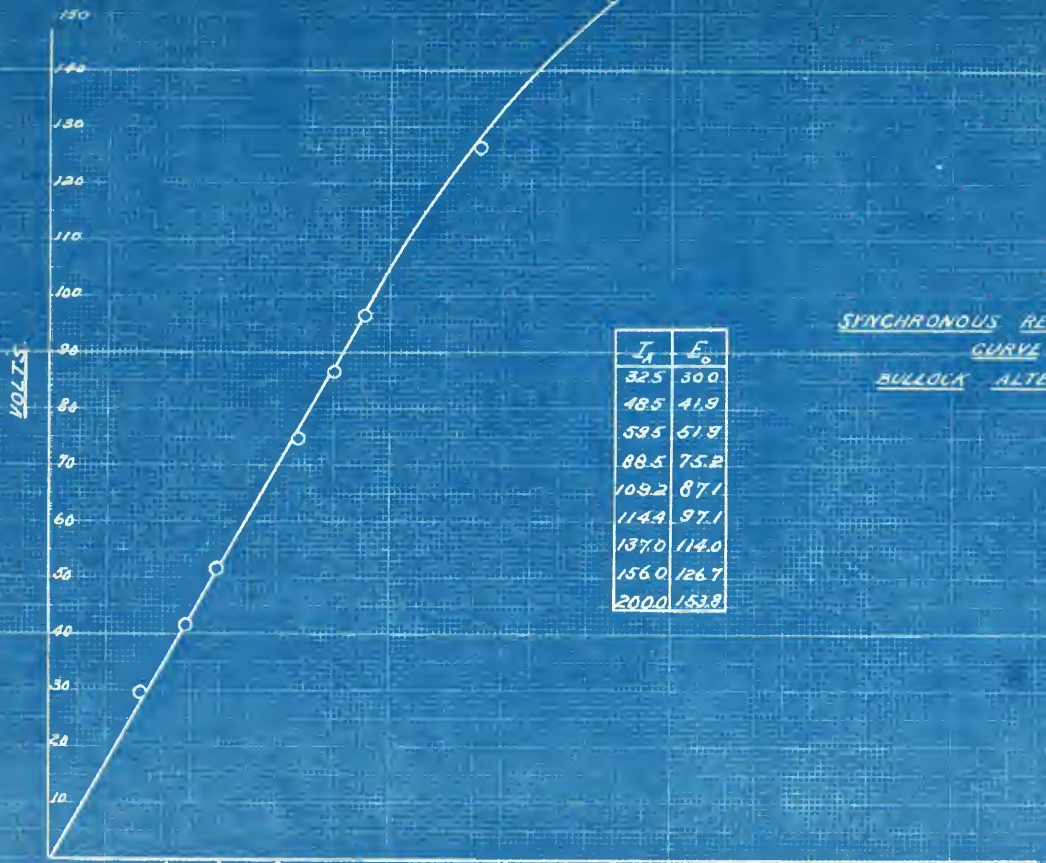


| $I_A$ | $E_o$ |
|---|---|
| 32.5 | 30.0 |
| 48.5 | 41.9 |
| 59.5 | 51.9 |
| 88.5 | 75.2 |
| 109.2 | 87.1 |
| 114.4 | 97.1 |
| 137.0 | 114.0 |
| 156.0 | 126.7 |
| 200.0 | 153.8 |

SYNCHRONOUS REACTANCE CURVE

BULLOCK ALTERNATOR

CURVE SHEET No 16

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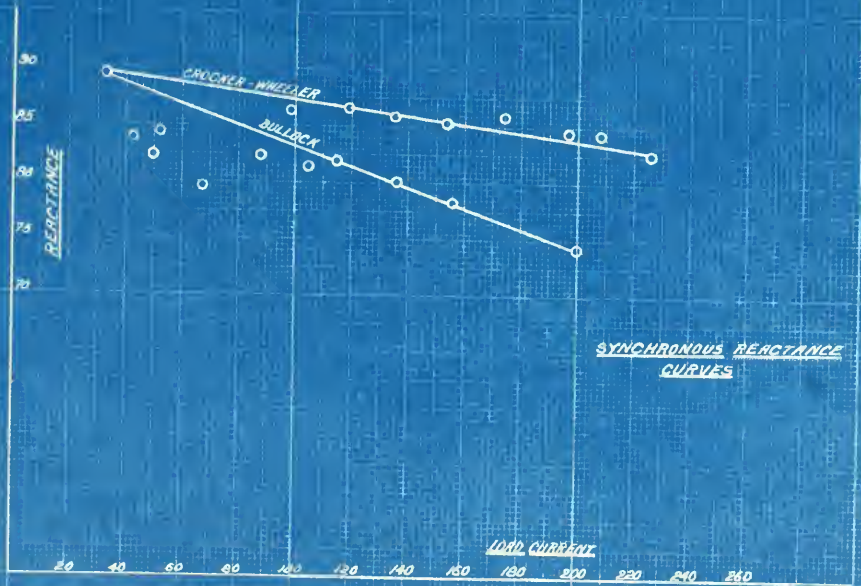


SYNCHRONOUS REACTANCE CURVES

CURVE SHEET No 17

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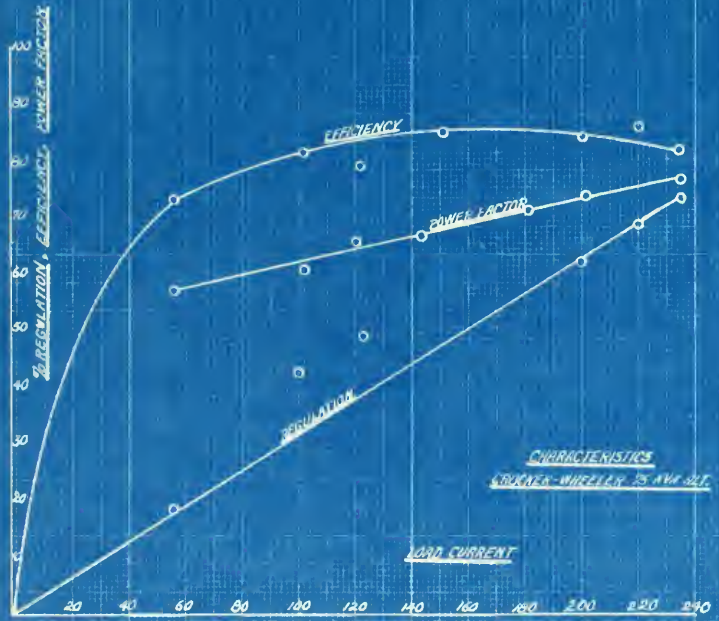


CURVE SHEET No 18

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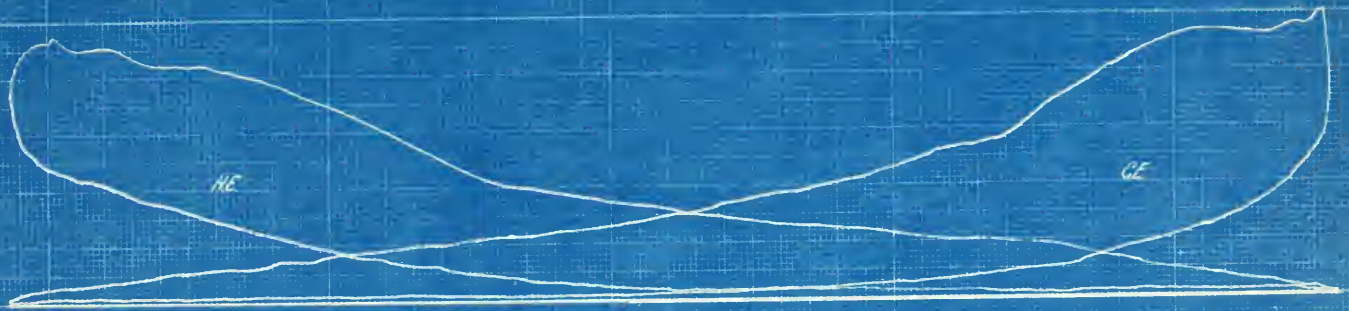
## Sample Indicator Card

SKINNER ENGINE  Scale 2" = 1"

HORSE POWER FROM CARD 70.73
MEDIUM LOAD #2




ATMOSPHERIC LINE

CURVE SHEET No 20

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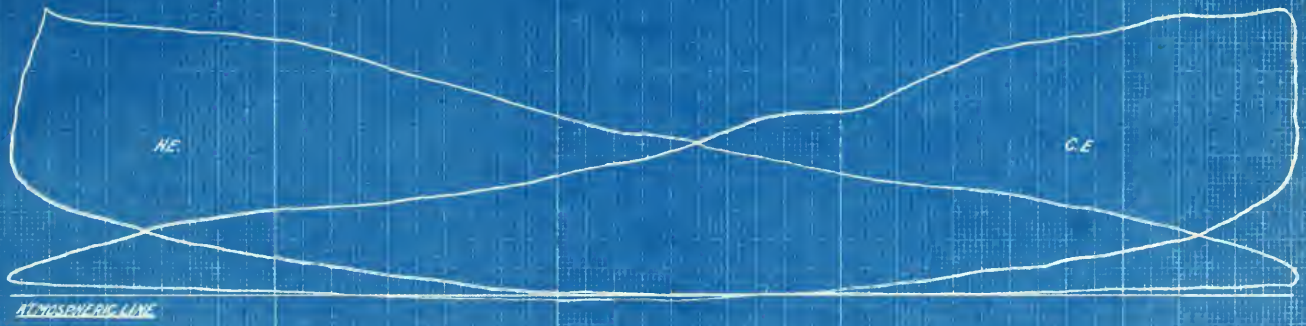
Sample Indicator Card
SKINNER ENGINE - Scale DOUBLE SIZE
HORSEPOWER FROM CARD 120.64
FULL LOAD CARD # 9




CURVE SHEET № 21.

ARCHIVES
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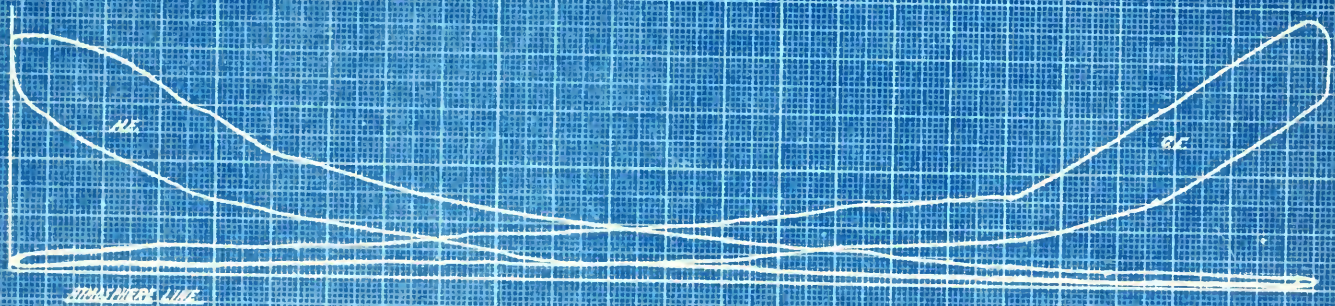
SAMPLE H.P. CARD
SKINNER ENGINE DOUBLE SIZE
LIGHT LOAD




CURVE SHEET No. 2

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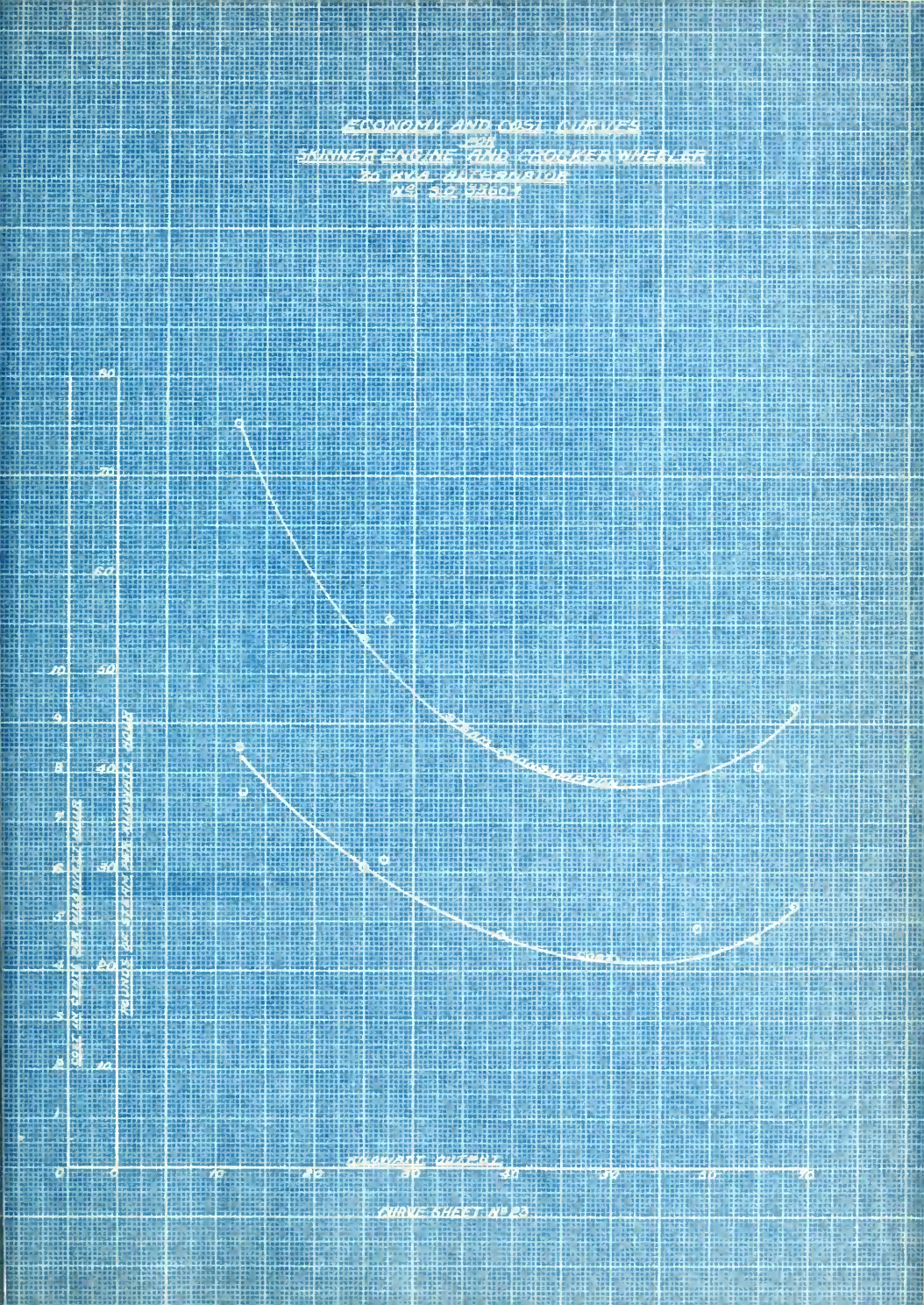
ECONOMY AND COST CURVES
FOR
SKINNER ENGINE AND CROCKER WHEELER
36 KVA ALTERNATOR
No. 30 93607
COST IN CENTS PER KILOWATT HOUR
POUNDS OF STEAM PER KILOWATT HOUR
KILOWATT OUTPUT
CURVE SHEET No 23

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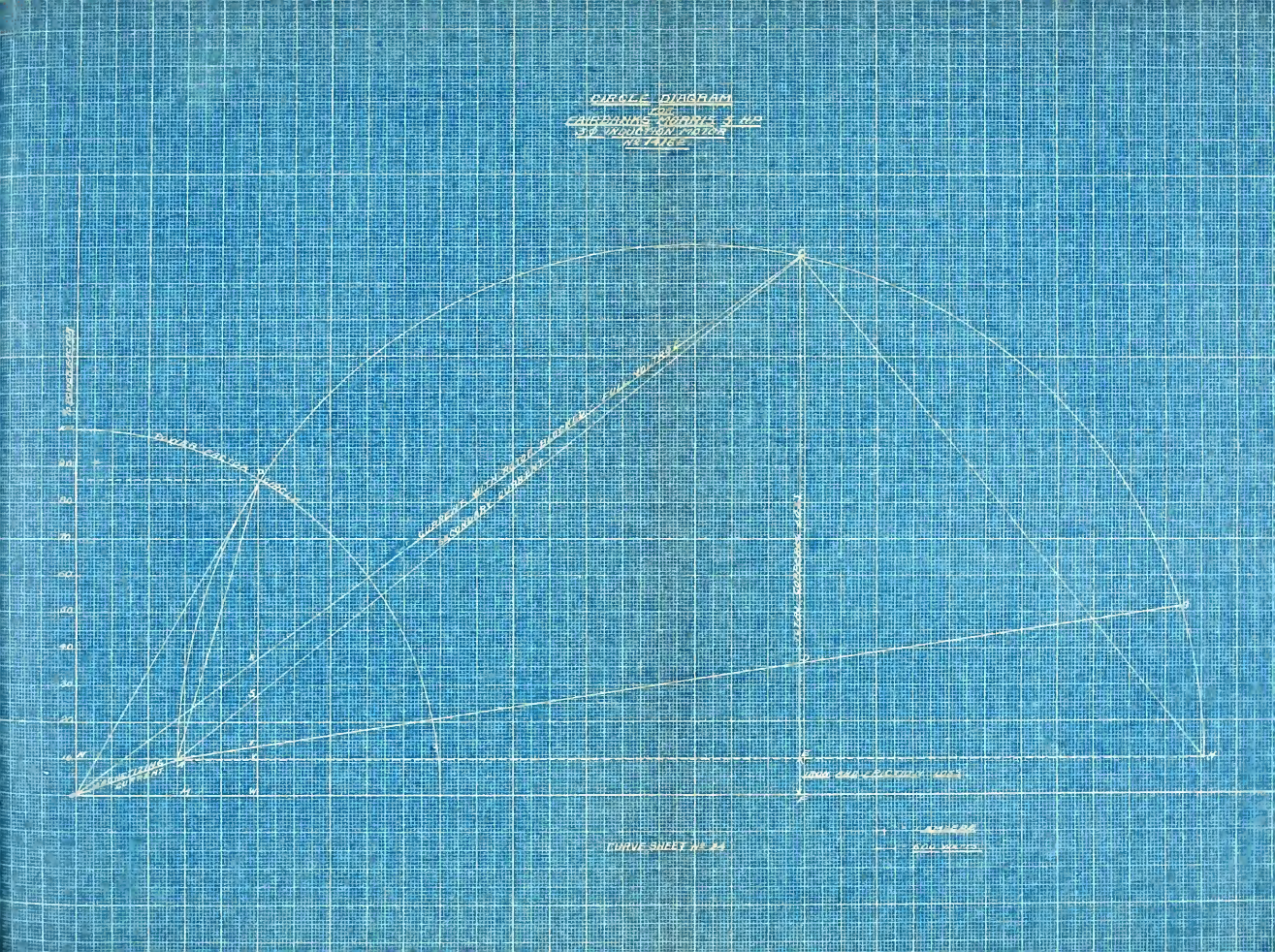
CIRCLE DIAGRAM
FOR
FAIRBANKS MORRIS 3 HP
3φ INDUCTION MOTOR
CURVE SHEET No 24

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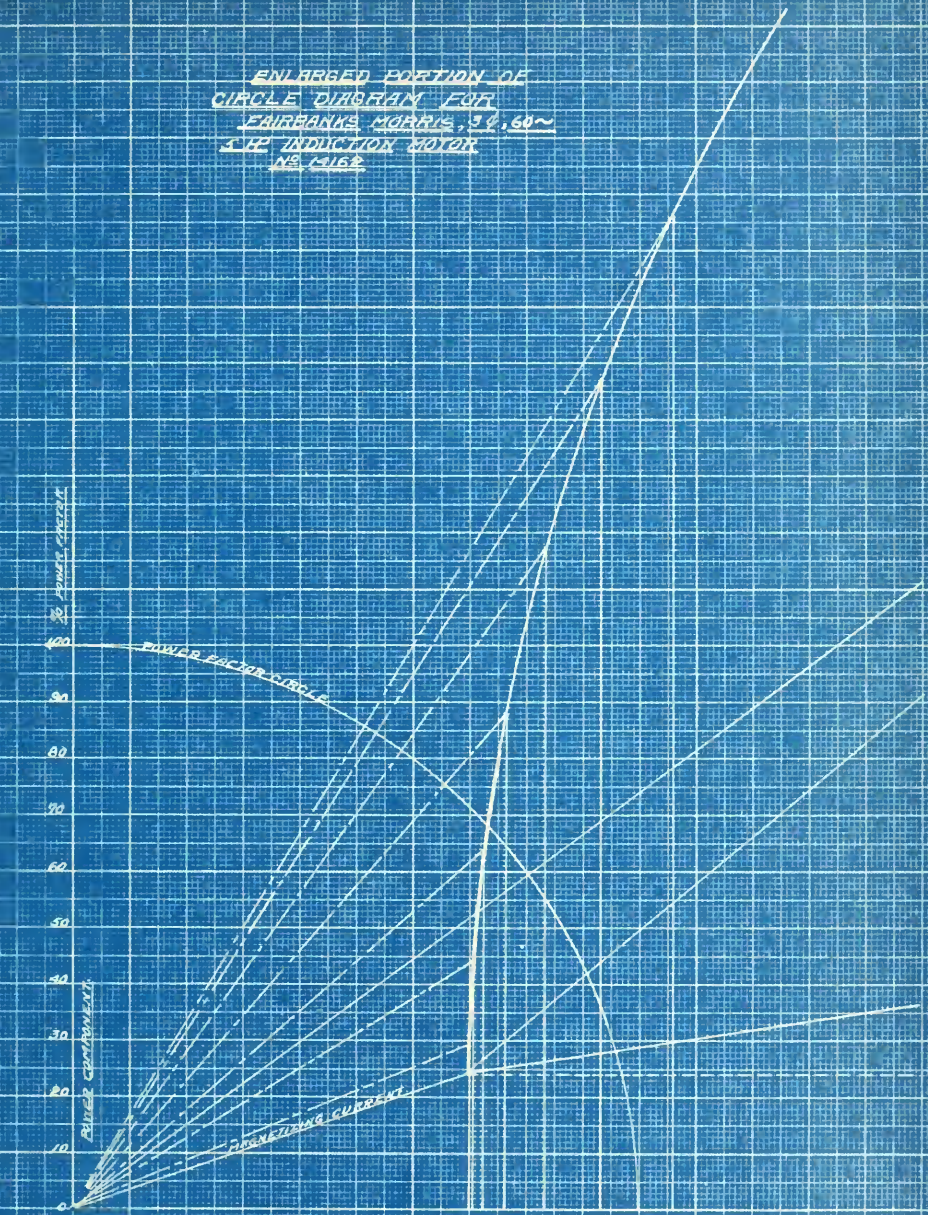
LIBRARY

ENLARGED PORTION OF
CIRCLE DIAGRAM FOR
FAIRBANKS MORRIS, 3 ϕ, 60~
5 HP INDUCTION MOTOR
No. 14162




CURVE SHEET NR 95

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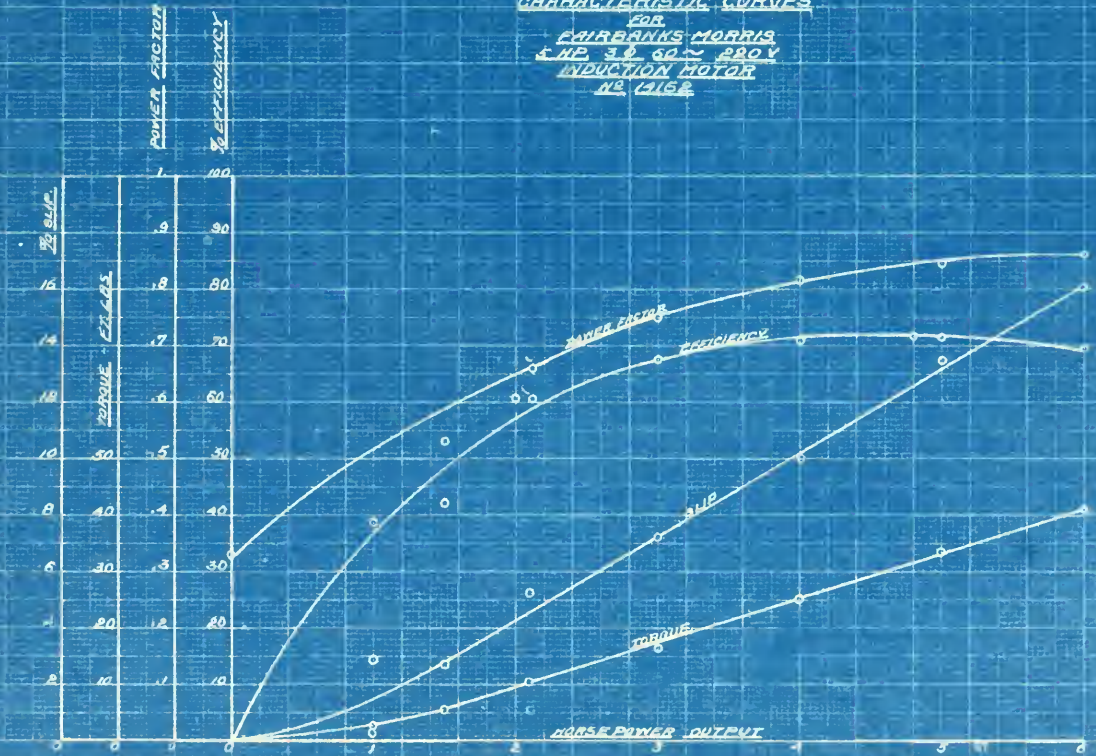
# CHARACTERISTIC CURVES
FOR
FAIRBANKS MORRIS
½ HP. 3 ϕ 60 ~ 220 V
INDUCTION MOTOR
Nº 121682




CURVE SHEET Nº 26

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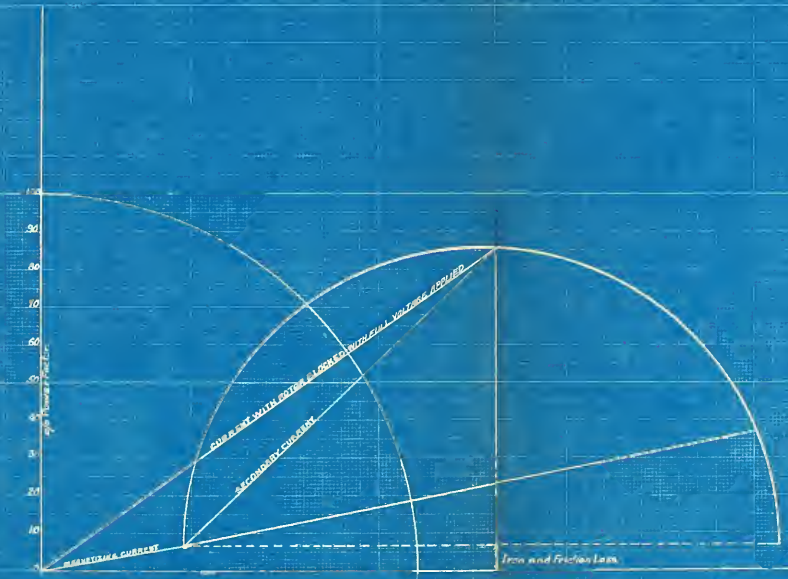
CIRCLE DIAGRAM
FOR
Westinghouse 1 H.P.
3 ϕ 60 Cycle Induction Motor
No 477361




CURVE SHEET No 47

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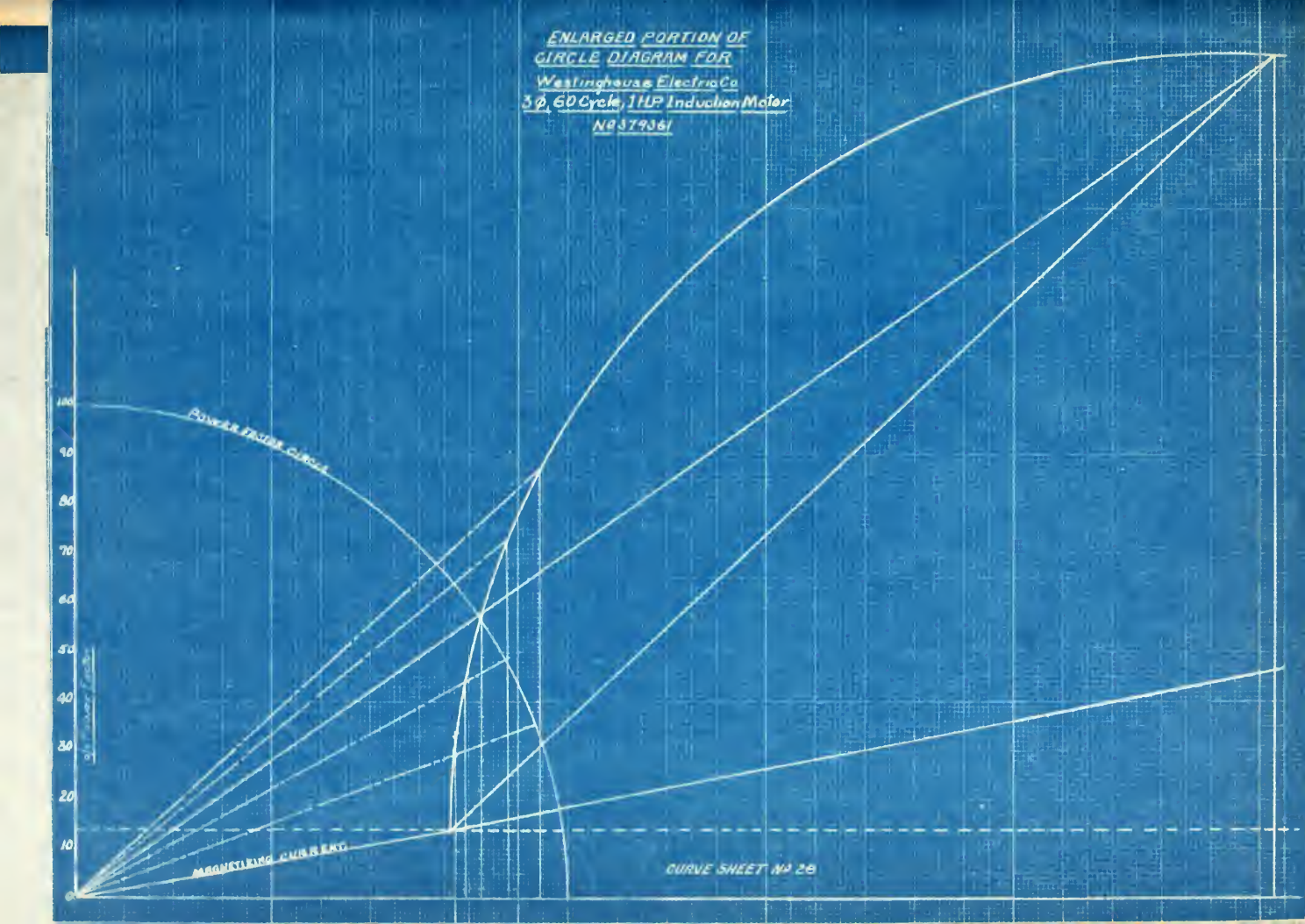
ENLARGED PORTION OF
CIRCLE DIAGRAM FOR
Westinghouse Electric Co
3 φ, 60 Cycle, 1 H.P. Induction Motor
No 379361
POWER FACTOR CURVE
MAGNETIZING CURRENT
CURVE SHEET No 28

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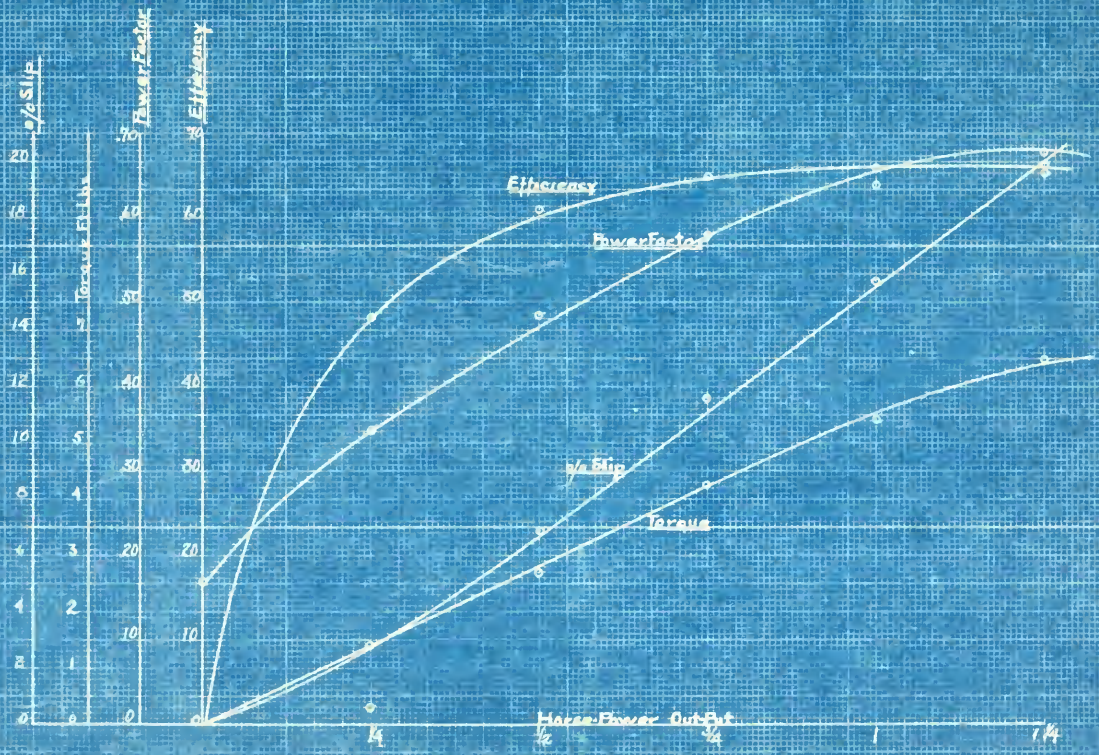
# CHARACTERISTIC CURVES
For
Westinghouse
1 H.P. 2 Ø 60 ~ 220 V
INDUCTION MOTOR
No 379361




CURVE SHEET No 29

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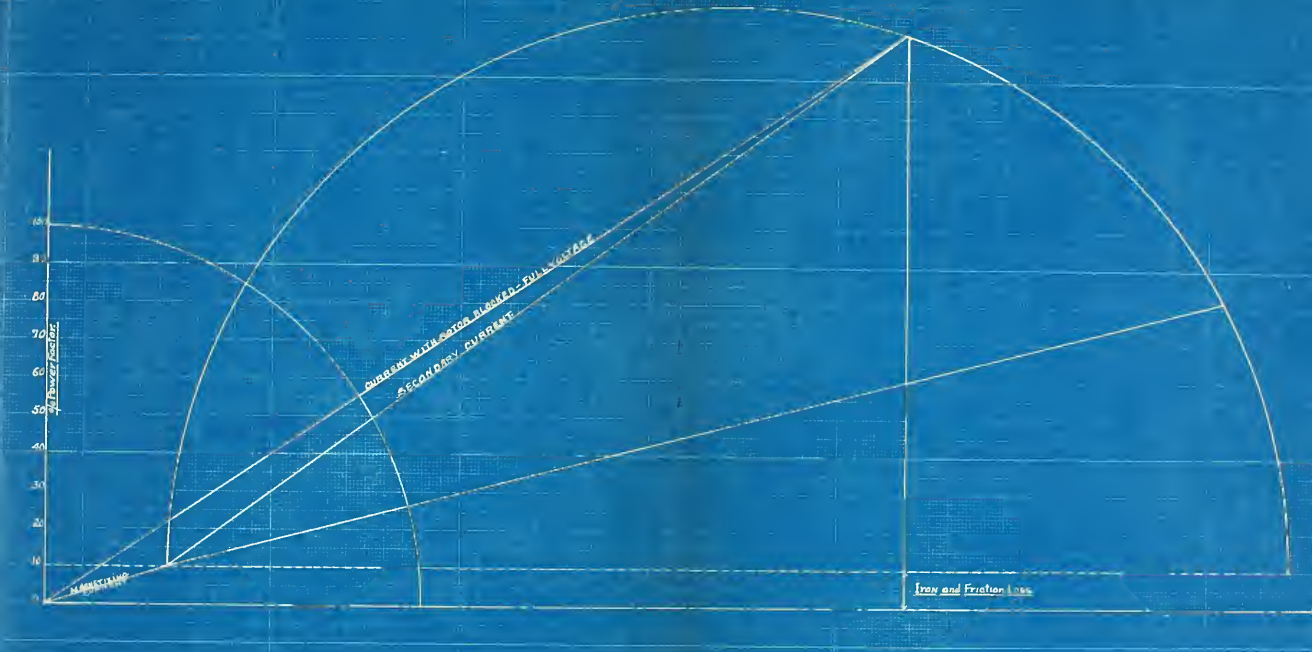
CIRCLE DIAGRAM
FOR
Westinghouse 5 HP
3φ 60 Cycle Induction Motor
No 265 E.C.




CURVE SHEET No 31

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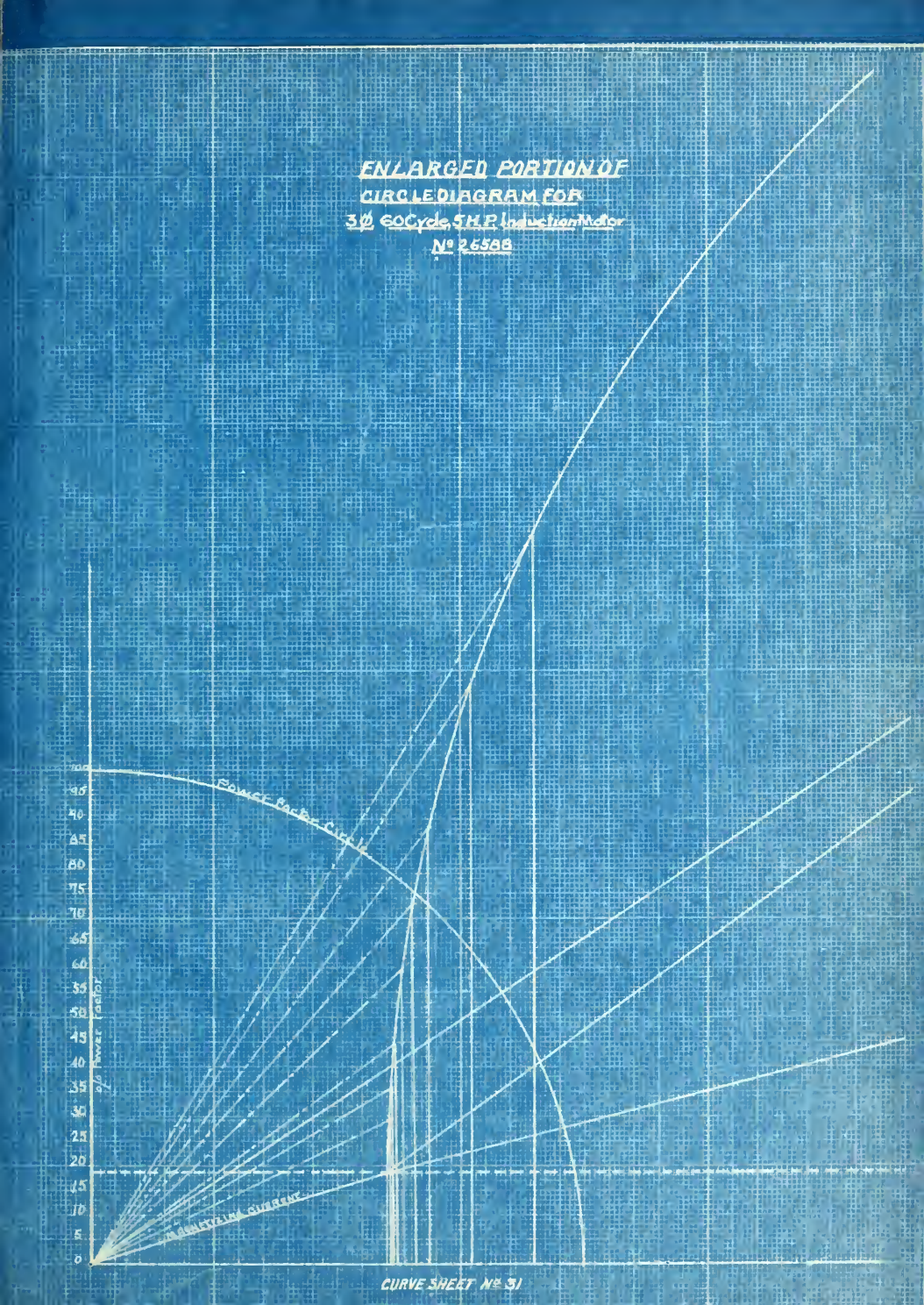
# ENLARGED PORTION OF CIRCLE DIAGRAM FOR 3Ø 60 Cycle, 5 H.P. Induction Motor Nº 26588




CURVE SHEET Nº 31

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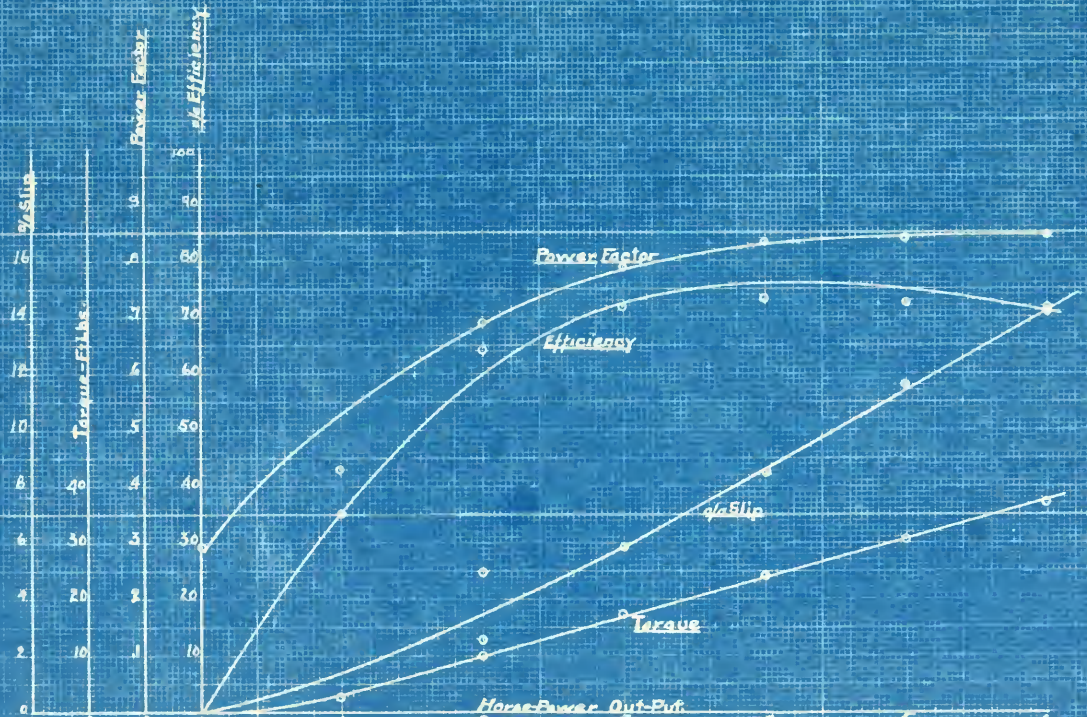
# CHARACTERISTIC CURVES
## for
## Westinghouse
## 5 H.P. 3Ø 60~ 220V.
## INDUCTION MOTOR
## No 26550




CURVE SHEET No 32

## BOILERS

KIND — Horizontal fire tube

MADE BY — Erie City Iron Works Erie, Pa.

LENGTH — 20 ft. DIAMETER 6 ft.

NUMBER OF TUBES — 72 DIAMETER OF TUBES — 4"

SQUARE FEET OF HEATING SURFACE — 1663

## GRATES

KIND — CAIN

MADE BY — Green Engineering Co.

LENGTH — 8 ft. WIDTH — 5 ft. AREA — 40 sq ft.

RATIO OF HEATING SURFACE TO GRATE SURFACE — 42

## CHIMNEY

TYPE — Brick

HEIGHT — 125 ft. INSIDE DIAMETER — 8½ ft.

LENGTH OF BREECHING — 49' DIAMETER — 36" & 64"

LENGTH OF FLUE FROM BOILER TO BREECHING.

METHOD OF STARTING TEST — "Alternate"

DURATION OF TRIALS — 8 hours.

LOAD CARRIED BY BOILER UNDER TEST — Maximum.

KIND OF COAL USED. — ILLINOIS

DATE OF TRIALS

BOILER No 1 — DEC. 30, 08

BOILER No 2 — DEC. 23, 08

BOILER No 3 — DEC. 31, 08

BOILER No 4 — JAN. 2, 09

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# RUNNING LOG
## BOILER No 1

| TIME | DRAFT | TEMPERATURES | | | QUALITY OF STEAM | | | BOILER FEED WATER | | | COAL | | | FLUE GAS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME OF TAKING READINGS | DRAFT IN FLUE | OUTSIDE AIR | BOILER ROOM | FLUE GAS | TEMP IN CALORIMETER | STEAM PRESSURE | PER CENT DRYNESS | WATER METER READINGS | QUANTITY USED | TEMP OF WATER | TARE | GROSS | NET | PER CENT $CO_2$ | PER CENT O |
| 7:45 | .45 | 34 | 77 | 452 | 270 | 103 | 98.72 | 7781650 | 0 | 202 | | | | | |
| 8:00 | .35 | 34 | 73 | 452 | 268 | 104 | 98.62 | 7781860 | 22 | 199 | 36 | 320 | 284 | 2.0 | 7 |
| 8:15 | .41 | 35 | 78 | 485 | 270 | 110 | 98.56 | 7782000 | 43 | 198 | 36 | 322 | 286 | | |
| 8:30 | .42 | 35 | 72 | 600 | 274 | 124 | 9848 | 7782180 | 547 | 199 | 54 | 483 | 429 | 2.5 | 7 |
| 8:45 | .41 | 35 | 70 | 530 | 276 | 121 | 98.66 | 7782430 | 75 | 201 | 54 | 315 | 261 | | |
| 9:00 | .42 | 35 | 71 | 527 | 274 | 123 | 98.52 | 7782810 | 110 | 201 | 54 | 463 | 409 | 2.0 | 4.5 |
| 9:15 | .43 | 36 | 68 | 608 | 278 | 124 | 98.71 | 7783180 | 138 | 202 | 72 | 629 | 557 | | |
| 9:30 | .42 | 37 | 78 | 582 | 276 | 121 | 98.66 | 7783620 | 175 | 201 | 54 | 449 | 395 | 2.0 | 6.0 |
| 9:45 | .42 | 37 | 81 | 612 | 278 | 124 | 98.71 | 7784050 | 219 | 201 | 54 | 468 | 414 | | |
| 10:00 | .43 | 38 | 80 | 614 | 276 | 122 | 98.65 | 7784250 | 262 | 202 | 36 | 317 | 281 | 3.0 | 7.0 |
| 10:15 | .38 | 39 | 80 | 565 | 279 | 118 | 98.89 | 7784540 | 282 | 202 | 36 | 321 | 285 | | |
| 10:30 | .42 | 39 | 78 | 545 | 283 | 124 | 9900 | 7784920 | 311 | 201 | 54 | 489 | 435 | 2.0 | 5.5 |
| 10:45 | .44 | 39 | 76 | 610 | 282 | 119 | 99.05 | 7785260 | 349 | 199 | 54 | 480 | 426 | | |
| 11:00 | .40 | 39 | 75 | 545 | 279 | 111 | 99.05 | 7785535 | 383 | 201 | 36 | 335 | 299 | 2 | 5.5 |
| 11:15 | .46 | 39 | 75 | 384 | 282 | 114 | 99.15 | 7785910 | 412 | 202 | 36 | 326 | 290 | | |
| 11:30 | .39 | 39 | 75 | 560 | 282 | 121 | 99.01 | 7786120 | 448 | 202 | 54 | 478 | 4240 | 2 | 4.5 |
| 11:45 | .44 | 39 | 77 | 582 | 283 | 122 | 99.04 | 7786410 | 469 | 202 | 72 | 663 | 591 | | |
| 12:00 | .39 | 38 | 73 | 545 | 282 | 120 | 99.03 | 7786770 | 498 | 199 | 18 | 174 | 156 | 2.5 | 5.5 |
| 12:15 | .49 | 37 | 74 | 574 | 284 | 125 | 98.98 | 7787010 | 534 | 197 | | | | | |
| 12:30 | .40 | 38 | 72 | 545 | 285 | 124 | 99.06 | 7787350 | 558 | 198 | | | | 2.0 | 4.0 |
| 12:45 | .42 | 38 | 74 | 580 | 283 | 123 | 99.02 | 7787560 | 592 | 200 | 126 | 952 | 826 | | |
| 1:00 | .40 | 37 | 75 | 550 | 279 | 111 | 99.06 | 7787840 | 613 | 200 | | | | 2.0 | 5.0 |
| 1:15 | .39 | 35 | 73 | 560 | 278 | 115 | 98.90 | 7788100 | 641 | 199 | 72 | 531 | 459 | | |
| 1:30 | .43 | 35 | 76 | 572 | 283 | 124 | 99.00 | 7788330 | 667 | 200 | 54 | 434 | 380 | 1.5 | 5.0 |
| 1:45 | .41 | 34 | 74 | 558 | 282 | 120 | 99.03 | 7788860 | 690 | 202 | 18 | 150 | 132 | | |
| 2:00 | .47 | 34 | 74 | 570 | 283 | 125 | 9898 | 7788920 | 717 | 199 | 54 | 497 | 443 | 2.5 | 6.0 |
| 2:15 | .38 | 36 | 74 | 580 | 283 | 124 | 99.00 | 7789250 | 749 | 200 | 54 | 399 | 345 | | |
| 2:30 | .46 | 32 | 72 | 601 | 280 | 118 | 98.85 | 7789470 | 782 | 200 | 18 | 143 | 125 | 2.0 | 5.0 |
| 2:45 | .40 | 34 | 72 | 580 | 282 | 125 | 98.93 | 7789820 | 804 | 200 | 36 | 326 | 291 | | |
| 3:00 | .44 | 33 | 74 | 570 | 281 | 119 | 98.99 | 7790280 | 839 | 200 | 36 | 337 | 301 | 2.5 | 4.0 |
| 3:15 | .43 | 31 | 72 | 580 | 281 | 114 | 99.09 | 7790470 | 885 | 200 | 36 | 345 | 309 | | |
| 3:30 | .41 | 32 | 72 | 580 | 281 | 115 | 99.07 | 7790920 | 904 | 200 | 54 | 543 | 489 | 2.5 | 5.0 |
| 3:45 | .42 | 30 | 74 | 580 | 281 | 117 | 9902 | 7791020 | 949 | 200 | 18 | 193 | 175 | | |

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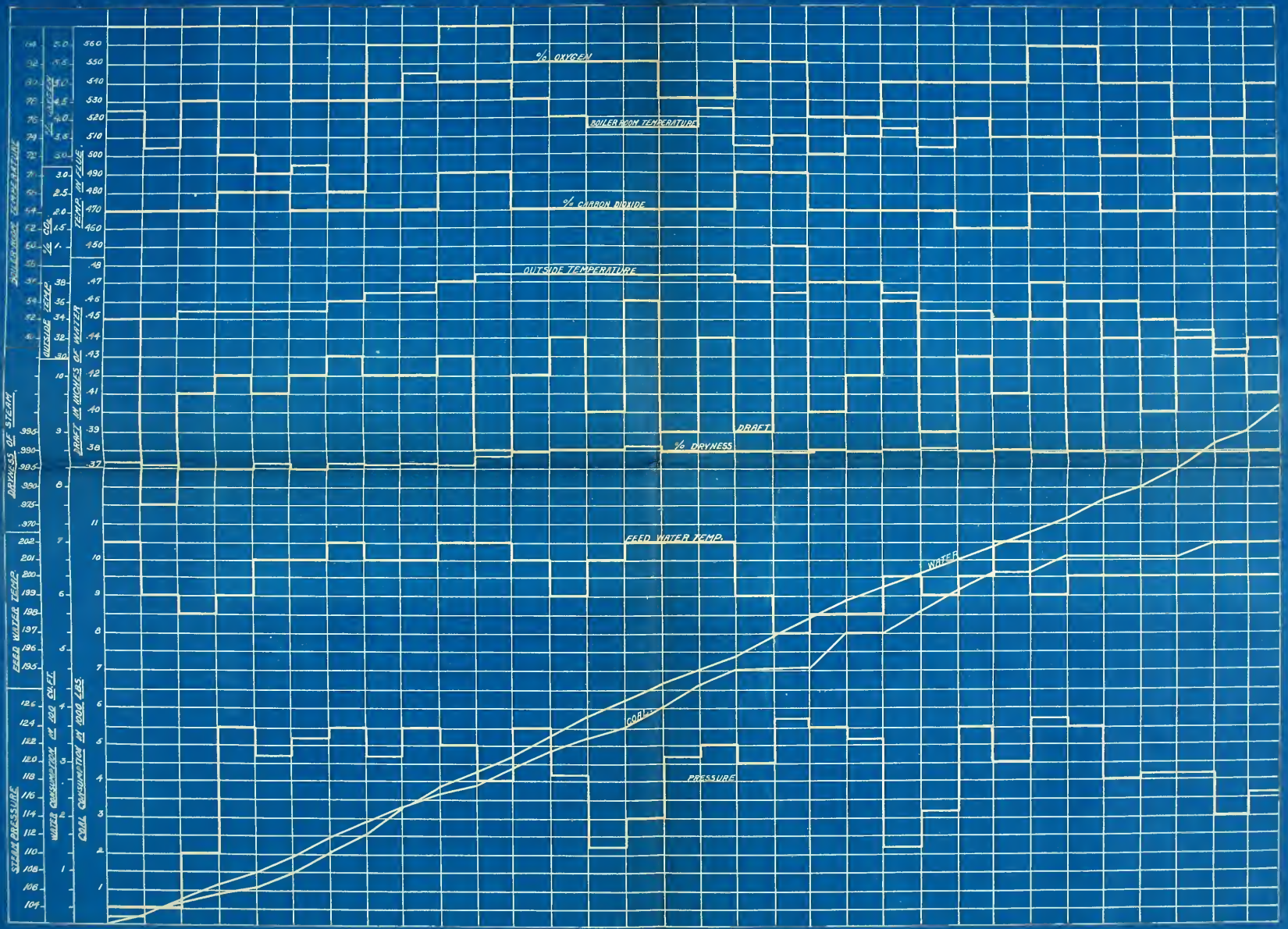
# GRAPHICAL LOG

## BOILER No. 1




DATA SHEET No. 13

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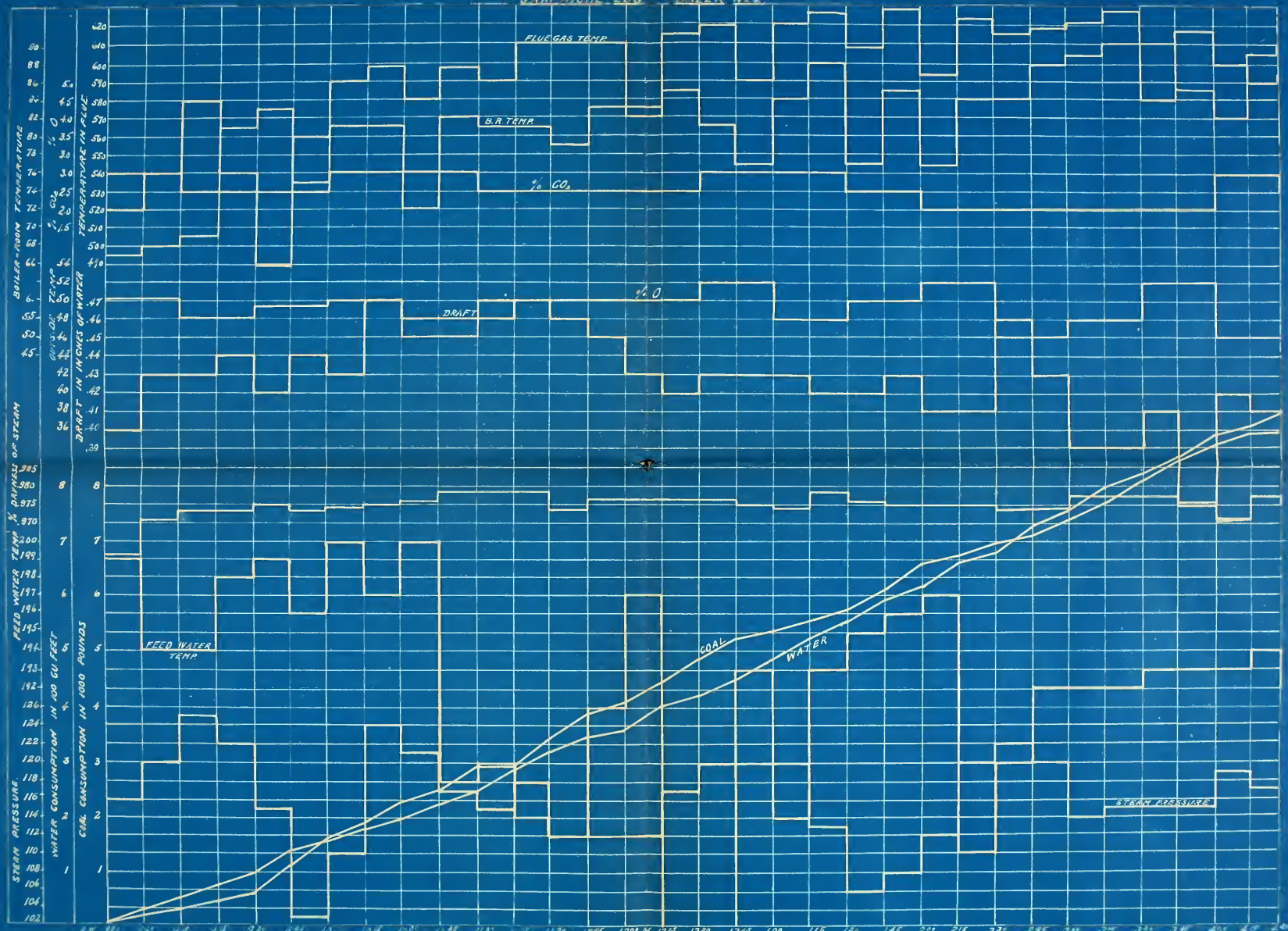


DATA SHEET No 14.

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# RUNNING LOG
## BOILER Nº 2

| TIME | DRAFT | TEMPERATURES. | | | QUALITY OF STEAM | | | BOILER FEED WATER. | | | COAL | | | FLUE GAS. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME OF TAKING READINGS. | DRAFT IN FLUE. | OUTSIDE AIR | BOILER ROOM | FLUE GAS | TEMP IN CALORIMETER | STEAM PRESSURE | PERCENT DRYNESS | WATER METER READING | QUANTITY USED | TEMP. OF WATER | TARE | GROSS | NET | PER CENT $CO_2$ | PER CENT O |
| 8 30 | .40 | 36 | 67 | 520 | 227 | 116 | .961 | 866215 | 0 | 199 | 18 | 187 | 169 | 3.0 | 6.1 |
| 8 45 | .43 | 36 | 68 | 540 | 247 | 120 | .971 | 866246 | 31 | 194 | 18 | 166 | 148 | | |
| 9 00 | .43 | 37 | 69 | 580 | 252 | 126 | .973 | 866268 | 53 | 194 | 18 | 175 | 157 | 2.5 | 5.5 |
| 9 15 | .44 | 37 | 81 | 540 | 253 | 122 | .973 | 866292 | 77 | 198 | 18 | 174 | 156 | | |
| 9 30 | .42 | 38 | 83 | 490 | 251 | 115 | .975 | 866322 | 107 | 199 | 36 | 321 | 285 | 2.5 | 5.8 |
| 9 45 | .44 | 38 | 75 | 560 | 242 | 103 | .973 | 866351 | 136 | 196 | 36 | 300 | 264 | | |
| 10 00 | .43 | 38 | 81 | 590 | 250 | 110 | .974 | 866373 | 158 | 200 | 72 | 602 | 530 | 3.0 | 6.0 |
| 10 15 | .47 | 38 | 81 | 598 | 256 | 124 | .975 | 866396 | 181 | 197 | 36 | 306 | 270 | | |
| 10 30 | .46 | 39 | 72 | 590 | 258 | 121 | .976 | 866412 | 197 | 200 | 54 | 437 | 383 | 3.0 | 5.0 |
| 10 45 | .46 | 40 | 81 | 598 | 256 | 117 | .978 | 866440 | 225 | 187 | 36 | 298 | 262 | | |
| 11 00 | .46 | 40 | 82 | 580 | 256 | 115 | .978 | 866470 | 255 | 188 | 54 | 456 | 402 | 2.5 | 6.0 |
| 11 15 | .47 | 40 | 81 | 610 | 256 | 118 | .978 | 866507 | 272 | 185 | — | — | — | | |
| 11 30 | .46 | 35 | 81 | 610 | 252 | 112 | .974 | 866538 | 323 | 184 | 54 | 494 | 440 | 2.5 | 6.0 |
| 11 45 | .45 | 41 | 79 | 610 | 254 | 112 | .976 | 866555 | 340 | 191 | 54 | 501 | 447 | | |
| 12 00 | .43 | 41 | 83 | 570 | 254 | 112 | .976 | 866580 | 365 | 197 | 36 | 334 | 298 | 2.5 | 6.0 |
| 12 15 | .42 | 42 | 83 | 614 | 264 | 117 | .976 | 866618 | 403 | 166 | 36 | 343 | 307 | | |
| 12 30 | .43 | 42 | 85 | 618 | 256 | 120 | .976 | 866642 | 427 | 178 | 54 | 459 | 406 | 3.0 | 6.5 |
| 12 45 | .43 | 43 | 81 | 590 | 255 | 120 | .975 | 866665 | 450 | 193 | 54 | 463 | 409 | | |
| 1 00 | .43 | 43 | 77 | 620 | 256 | 120 | .974 | 866701 | 486 | 185 | 18 | 152 | 134 | 3.0 | 5.5 |
| 1 15 | .42 | 43 | 84 | 625 | 265 | 113 | .978 | 866744 | 528 | 193 | 18 | 164 | 146 | | |
| 1 30 | .42 | 44 | 77 | 608 | 250 | 106 | .976 | 866777 | 562 | 195 | 36 | 309 | 273 | 2.5 | 6.0 |
| 1 45 | .43 | 44 | 84 | 628 | 251 | 108 | .975 | 866804 | 589 | 196 | 54 | 462 | 408 | | |
| 2 00 | .41 | 44 | 84 | 594 | 252 | 112 | .975 | 866836 | 621 | 197 | 54 | 466 | 412 | 2.0 | 6.5 |
| 2 15 | .41 | 53 | 88 | 622 | 253 | 120 | .975 | 866887 | 672 | 183 | 18 | 143 | 125 | | |
| 2 30 | .46 | 53 | 89 | 616 | 256 | 122 | .974 | 866908 | 688 | 188 | 36 | 284 | 248 | 2.0 | 5.0 |
| 2 45 | .43 | 52 | 90 | 618 | 254 | 120 | .974 | 866942 | 730 | 192 | 36 | 255 | 219 | | |
| 3 00 | .39 | 51 | 90 | 621 | 253 | 114 | .977 | 866977 | 762 | 192 | 54 | 394 | 340 | 2.0 | 5.5 |
| 3 15 | .39 | 49 | 90 | 626 | 255 | 115 | .977 | 867010 | 795 | 192 | 54 | 375 | 321 | | |
| 3 30 | .41 | 52 | 90 | 580 | 256 | 115 | .977 | 867038 | 823 | 193 | 54 | 405 | 351 | 2.0 | 6.5 |
| 3 45 | .36 | 51 | 85 | 617 | 251 | 115 | .976 | 867064 | 849 | 193 | 54 | 438 | 384 | | |
| 4 00 | .42 | 49 | 82 | 600 | 252 | 119 | .972 | 867086 | 891 | 193 | 36 | 319 | 283 | 3.0 | 5.0 |
| 4 15 | .41 | 47 | 87 | 590 | 255 | 117 | .977 | 867010 | 915 | 194 | 18 | 169 | 151 | | |
| 4 30 | .41 | 48 | 88 | 595 | 254 | 117 | .975 | 867148 | 933 | 192 | — | — | — | 2.5 | 5.0 |

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RUNNING LOG
BOILER No 3

| TIME | DRAFT | TEMPERATURES | | | QUALITY OF STEAM | | | BOILER FEED WATER | | | COAL | | | FLUE GAS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME OF TAKING READINGS | DRAFT IN FLUE | OUTSIDE AIR | BOILER-ROOM | FLUE GAS | TEMP. IN CALORIMETER | STEAM PRESSURE | PERCENT DRYNESS | WATER-METER READING | QUANTITY USED | TEMP. OF WATER | TARE | GROSS | NET | PERCENT $CO_2$ | PERCENT O. |
| | | | | | | | | | | | | | | | |
| $7^{30}$ | .38 | 16 | 60 | 480 | 265 | 120 | .981 | 770299 | 0 | 200 | | | | | |
| $7^{45}$ | .38 | 15 | 60 | 520 | 265 | 120 | .981 | 770323 | 24 | 200 | 54 | 436 | 382 | 2.5 | 5 |
| $8^{00}$ | .40 | 16 | 62 | 530 | 266 | 123 | .98 | 770357 | 58 | 193 | 36 | 279 | 243 | | |
| $8^{15}$ | .39 | 16 | 58 | 540 | 266 | 123 | .98 | 770382 | 83 | 199 | 90 | 735 | 645 | 2. | 4 |
| $8^{30}$ | .42 | 16 | 59 | 552 | 268 | 123 | .981 | 770405 | 106 | 199 | 54 | 438 | 384 | | |
| $8^{45}$ | .42 | 17 | 59 | 563 | 267 | 123 | .98 | 770426 | 127 | 202 | 72 | 571 | 499 | 2. | 3.5 |
| $9^{00}$ | .42 | 17 | 59 | 530 | 261 | 123 | .978 | 770457 | 158 | 202 | 18 | 141 | 123 | | |
| $9^{15}$ | .42 | 17 | 81 | 520 | 264 | 120 | .98 | 770491 | 192 | 200 | 54 | 425 | 371 | 1.5 | 3.5 |
| $9^{30}$ | .43 | 17 | 82 | 553 | 259 | 120 | .976 | 770517 | 218 | 200 | 18 | 139 | 121 | | |
| $9^{45}$ | .41 | 17 | 80 | 552 | 258 | 122 | .977 | 770528 | 229 | 202 | 72 | 557 | 485 | 2. | 3. |
| $10^{00}$ | .41 | 17 | 79 | 534 | 256 | 123 | .975 | 770550 | 251 | 204 | 36 | 283 | 247 | | |
| $10^{15}$ | .41 | 18 | 79 | 557 | 255 | 119 | .976 | 770573 | 274 | 204 | 18 | 141 | 123 | 1.5 | 3.5 |
| $10^{30}$ | .44 | 18 | 78 | 573 | 252 | 123 | .973 | 770600 | 301 | 200 | 36 | 285 | 249 | | |
| $10^{45}$ | .43 | 19 | 77 | 585 | 251 | 124 | .971 | 770620 | 321 | 200 | 72 | 561 | 489 | 2 | 4 |
| $11^{00}$ | .42 | 19 | 82 | 572 | 251 | 118 | .973 | 770665 | 366 | 200 | 36 | 280 | 244 | | |
| $11^{15}$ | .45 | 19 | 81 | 557 | 253 | 115 | .976 | 770692 | 393 | 197 | 54 | 420 | 366 | 2. | 4. |
| $11^{30}$ | .44 | 19 | 80 | 573 | 254 | 112 | .976 | 770719 | 420 | 194 | 72 | 633 | 561 | | |
| $11^{45}$ | .45 | 21 | 84 | 530 | 254 | 109 | .981 | 770741 | 442 | 195 | — | — | — | 1.5 | 3.5 |
| $12^{00}$ | .40 | 22 | 76 | 510 | 256 | 105 | .981 | 770768 | 469 | 199 | — | — | — | | |
| $12^{15}$ | .40 | 22 | 81 | 528 | 251 | 108 | .977 | 770792 | 493 | 197 | 18 | 153 | 135 | 1.5 | 3.5 |
| $12^{30}$ | .41 | 23 | 81 | 540 | 250 | 110 | .971 | 770818 | 519 | 198 | 54 | 472 | 418 | | |
| $12^{45}$ | .39 | 24 | 76 | 512 | 250 | 111 | .972 | 770842 | 543 | 199 | 36 | 319 | 283 | 1.5 | 3. |
| $1^{00}$ | .38 | 24 | 78 | 490 | 252 | 110 | .973 | 770862 | 563 | 199 | 18 | 168 | 150 | | |
| $1^{15}$ | .44 | 24 | 81 | 514 | 253 | 112 | .976 | 770885 | 586 | 198 | 54 | 522 | 468 | 1.7 | 3.8 |
| $1^{30}$ | .44 | 24 | 81 | 540 | 252 | 123 | .972 | 770908 | 609 | 197 | — | — | — | | |
| $1^{45}$ | .45 | 24 | 78 | 572 | 254 | 123 | .974 | 770928 | 629 | 196 | 18 | 174 | 156 | 1.7 | 3. |
| $2^{00}$ | .44 | 24 | 78 | 584 | 256 | 125 | .975 | 770946 | 647 | 195 | 36 | 341 | 305 | | |
| $2^{15}$ | .46 | 26 | 80 | 503 | 256 | 118 | .977 | 770973 | 674 | 195 | 18 | 178 | 160 | 2 | 3 |
| $2^{30}$ | .44 | 26 | 83 | 548 | 253 | 119 | .974 | 771002 | 703 | 196 | — | — | — | | |
| $2^{45}$ | .46 | 26 | 80 | 528 | 252 | 118 | .974 | 771024 | 725 | 197 | 54 | 498 | 444 | 2.5 | 3.5 |
| $3^{00}$ | .41 | 26 | 83 | 565 | 254 | 123 | .975 | 771045 | 746 | 197 | 36 | 341 | 305 | | |
| $3^{15}$ | .45 | 26 | 84 | 546 | 256 | 122 | .975 | 771064 | 765 | 197 | — | — | — | 2.5 | 3.5 |
| $3^{30}$ | .46 | 26 | 84 | 550 | 256 | 120 | .976 | 771089 | 790 | 197 | — | — | — | | |

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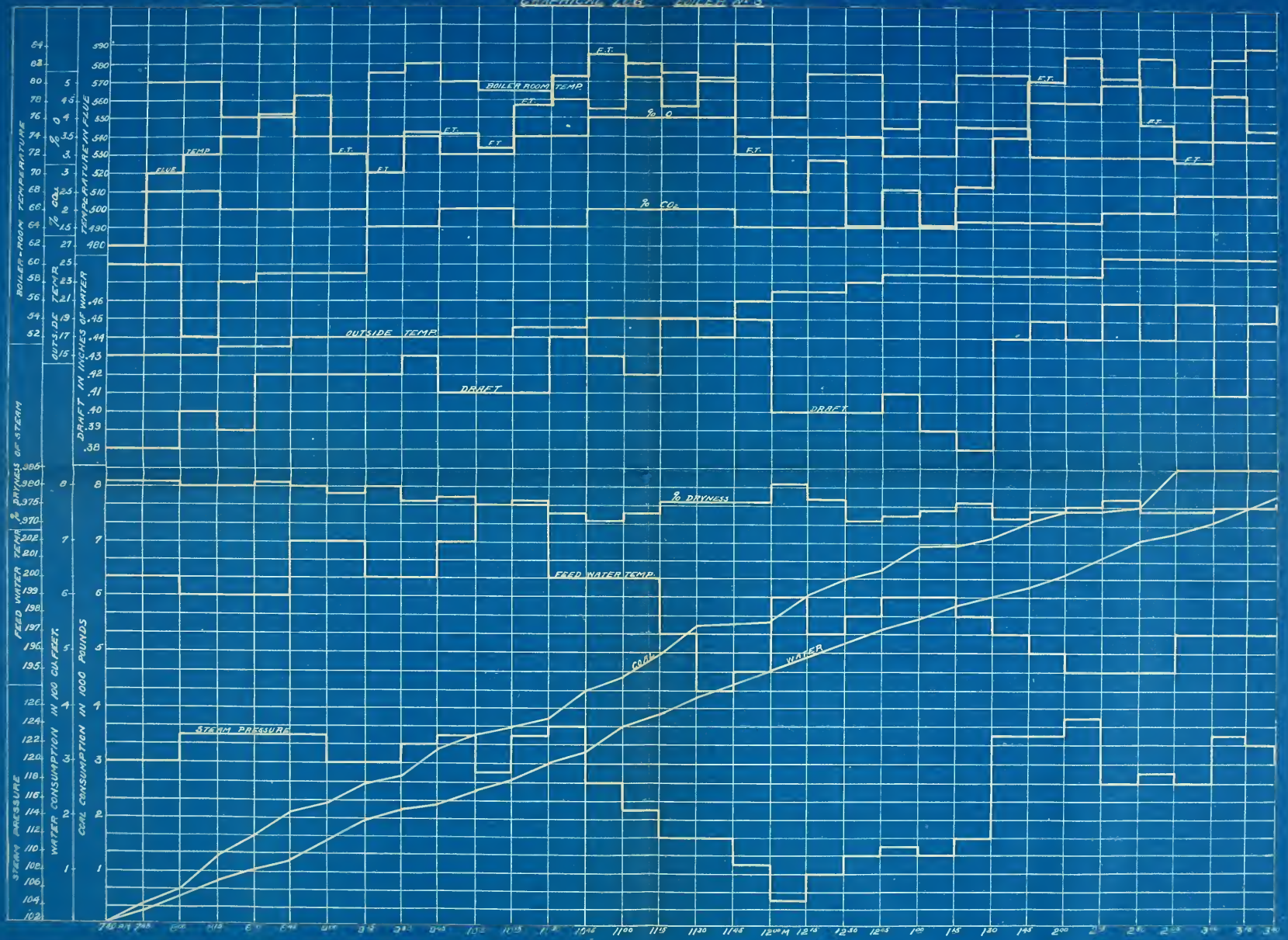
GRAPHICAL LOG BOILER No 3
BOILER-ROOM TEMPERATURE
% O
% CO2
TEMPERATURE IN FLUE
OUTSIDE TEMP.
DRAFT IN INCHES OF WATER
% DRYNESS OF STEAM
FEED WATER TEMP.
WATER CONSUMPTION IN 100 CU. FEET.
COAL CONSUMPTION IN 1000 POUNDS
STEAM PRESSURE
BOILER ROOM TEMP.
FLUE
TEMP
F.T.
% O
% CO2
OUTSIDE TEMP.
DRAFT
% DRYNESS
FEED WATER TEMP.
COAL
WATER
STEAM PRESSURE
DATA SHEET No 17

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RUNNING LOG
BOILER No 4

| TIME | DRAFT | TEMPERATURES | | | QUALITY OF STEAM | | | BOILER FEED WATER | | | COAL | | | FLUE GAS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME OF TAKING READINGS | DRAFT IN FLUE | OUTSIDE AIR | BOILER-ROOM | FLUE GAS | TEMP IN CALORIMETER | STEAM PRESSURE | PERCENT DRYNESS | WATER METER READINGS | QUANTITY USED | TEMP. OF WATER | TARE | GROSS | NET | PERCENT $CO_2$ | PERCENT O |
| | | | | | | | | | | | | | | | |
| 7 30 | .36 | 29 | 85 | 538 | 247 | 111 | 97.68 | 772102 | 0 | 201 | | | | | |
| 7 45 | .36 | 29 | 85 | 538 | 247 | 111 | 9728 | 772128 | 26 | 201 | 72 | 682 | 610 | 3.5 | 4 |
| 8 00 | .36 | 29 | 83 | 538 | 248 | 111 | 9738 | 772147 | 45 | 201 | 54 | 510 | 456 | | |
| 8 15 | .37 | 29 | 84 | 538 | 250 | 111 | 9744 | 772176 | 74 | 201 | 54 | 503 | 449 | 3.5 | 4 |
| 8 30 | .37 | 29 | 85 | 538 | 258 | 112 | 9753 | 772207 | 105 | 202 | 18 | 158 | 140 | | |
| 8 45 | .36 | 27 | 82 | 518 | 254 | 117 | 97.53 | 772230 | 128 | 202 | 72 | 660 | 588 | 3. | 4 |
| 9 00 | .38 | 27 | 85 | 546 | 261 | 121 | 97.64 | 772260 | 158 | 204 | 36 | 343 | 307 | | |
| 9 15 | .34 | 27 | 85 | 540 | 259 | 116 | 9783 | 772284 | 182 | 202 | 36 | 362 | 326 | 3.5 | 3 |
| 9 30 | .35 | 27 | 75 | 530 | 254 | 110 | 97.67 | 772308 | 206 | 202 | 18 | 182 | 164 | | |
| 9 45 | .39 | 28 | 75 | 534 | 254 | 118 | 97.51 | 772335 | 233 | 202 | 18 | 160 | 142 | 4 | 3 |
| 10 00 | .41 | 28 | 74 | 550 | 257 | 124 | 97.55 | 772362 | 260 | 204 | 36 | 342 | 306 | | |
| 10 15 | .39 | 28 | 74 | 510 | 259 | 122 | 9771 | 772388 | 286 | 204 | 72 | 688 | 616 | 2.5 | 4.5 |
| 10 30 | .41 | 29 | 76 | 515 | 257 | 121 | 97.61 | 772428 | 326 | 204 | 36 | 339 | 303 | | |
| 10 45 | .41 | 29 | 76 | 545 | 261 | 122 | 97.82 | 772442 | 340 | 204 | 36 | 356 | 320 | 3.5 | 3.5 |
| 11 00 | .42 | 29 | 75 | 545 | 259 | 126 | 97.62 | 772461 | 359 | 204 | 36 | 299 | 263 | | |
| 11 15 | .39 | 29 | 76 | 520 | 256 | 120 | 97.58 | 772495 | 393 | 204 | 54 | 391 | 337 | 2.5 | 3.5 |
| 11 30 | .41 | 29 | 76 | 540 | 259 | 120 | 97.74 | 772529 | 427 | 204 | 36 | 293 | 257 | | |
| 11 45 | .42 | 29 | 76 | 540 | 258 | 125 | 97.59 | 772554 | 452 | 203 | 54 | 546 | 492 | 3 | 4 |
| 12 00 | .40 | 30 | 77 | 540 | 259 | 124 | 97.66 | 772575 | 473 | 203 | — | — | — | | |
| 12 15 | .41 | 30 | 75 | 530 | 258 | 124 | 97.61 | 772602 | 500 | 203 | 18 | 181 | 163 | 3 | 4 |
| 12 30 | .41 | 31 | 76 | 537 | 256 | 120 | 97.58 | 772629 | 527 | 203 | 36 | 364 | 328 | | |
| 12 45 | .37 | 31 | 73 | 572 | 255 | 122 | 97.49 | 772677 | 575 | 203 | 36 | 357 | 321 | 2.5 | 3.5 |
| 1 00 | .38 | 31 | 76 | 518 | 257 | 120 | 97.63 | 772709 | 607 | 203 | 18 | 183 | 165 | | |
| 1 15 | .35 | 31 | 75 | 508 | 258 | 120 | 97.69 | 772728 | 626 | 202 | 54 | 539 | 485 | 2.5 | 3.5 |
| 1 30 | .37 | 31 | 78 | 516 | 257 | 120 | 97.64 | 772750 | 648 | 203 | 36 | 340 | 304 | | |
| 1 45 | .37 | 31 | 75 | 525 | 257 | 120 | 97.63 | 772772 | 670 | 204 | 18 | 171 | 153 | 2.5 | 3.5 |
| 2 00 | .37 | 31 | 77 | 530 | 253 | 120 | 9774 | 772794 | 692 | 204 | 18 | 175 | 157 | | |
| 2 15 | .37 | 31 | 79 | 530 | 256 | 120 | 97.58 | 772824 | 722 | 204 | 18 | 176 | 158 | 2.5 | 4 |
| 2 30 | .37 | 32 | 79 | 535 | 254 | 120 | 9747 | 772837 | 835 | 204 | 18 | 178 | 160 | | |
| 2 45 | .37 | 32 | 79 | 530 | 253 | 118 | 97.46 | 772862 | 760 | 204 | 54 | 404 | 350 | 2.5 | 3 |
| 3 00 | .37 | 32 | 79 | 515 | 250 | 120 | 9705 | 772887 | 785 | 204 | — | — | — | | |
| 3 15 | .38 | 32 | 80 | 510 | 249 | 122 | 97.15 | 772925 | 823 | 203 | — | — | — | 2.5 | 4. |
| 3 30 | .38 | 32 | 79 | 512 | 251 | 120 | 97.31 | 772939 | 837 | 202 | — | — | — | | |

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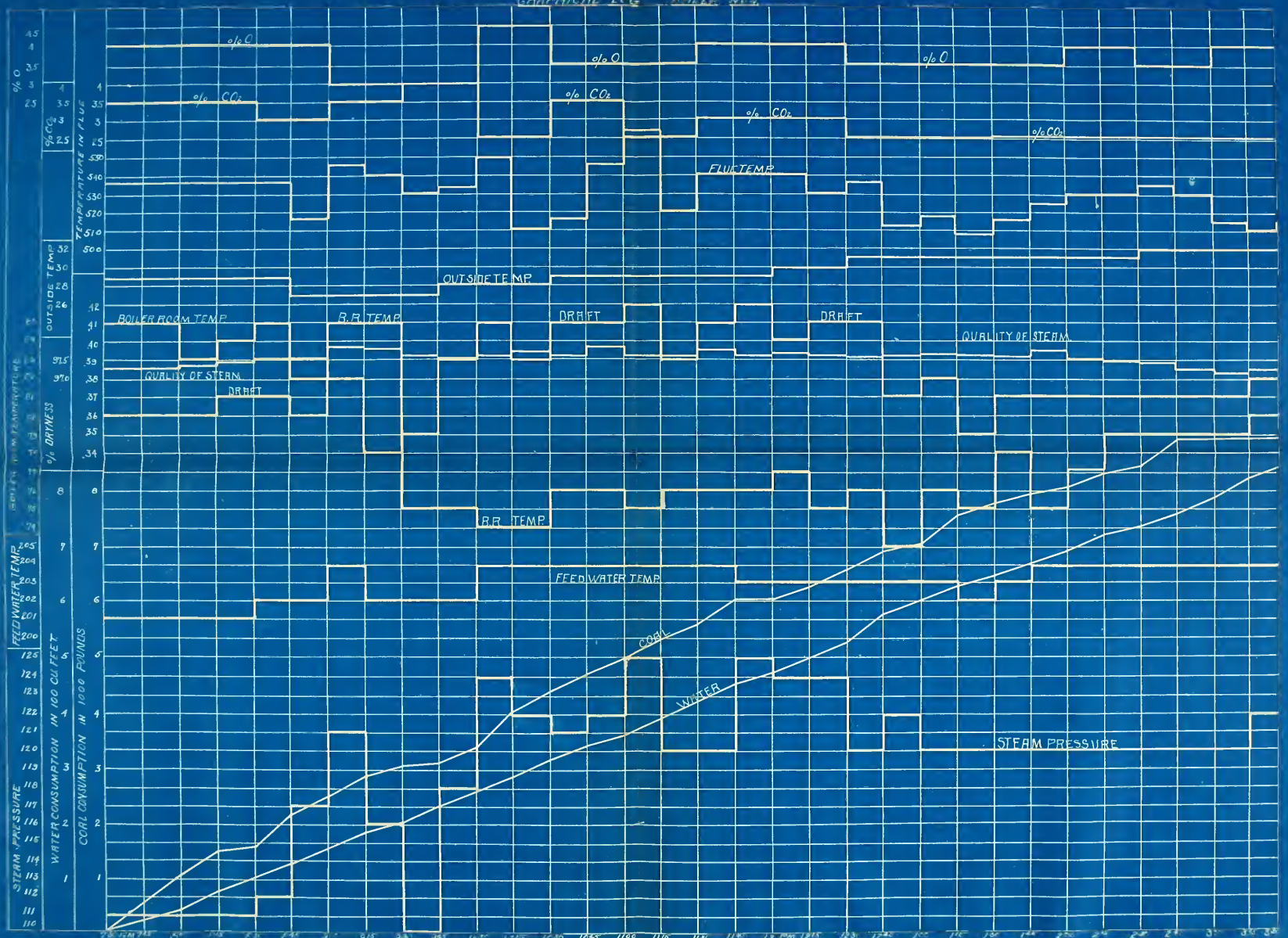
GRAPHICAL LOG BOILER No 1
% O
% CO2
FLUE TEMP
OUTSIDE TEMP
BOILER ROOM TEMP
B.R. TEMP
DRAFT
QUALITY OF STEAM
FEEDWATER TEMP
COAL
WATER
STEAM PRESSURE
TEMPERATURE IN FLUE
% CO2
OUTSIDE TEMP
% DRYNESS
FEEDWATER TEMP
WATER CONSUMPTION IN 100 CU FEET
COAL CONSUMPTION IN 1000 POUNDS
STEAM PRESSURE
DATA SHEET No 19.

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# RESULTS OF BOILER TESTS

| BOILER NUMBER | | 1 | 2 | 3 | 4 | AVERAGE |
|---|---|---|---|---|---|---|
| AVERAGE PRESSURES | | | | | | |
| Steam pressure by gauge - lbs. per sq in. | | 118.91 | 116.12 | 119 | 116 | 117.5 |
| Force of draft between damper and boiler - inches of water | | .3806 | .4282 | .4215 | .3809 | .4029 |
| AVERAGE TEMPERATURES. | | | | | | |
| Of external air | °F | 32.85 | 43.15 | 20.5 | 29.66 | 31.54 |
| Of fireroom | °F | 74.5 | 84.78 | 75.5 | 78.3 | 78.27 |
| Of steam in throttling calorimeter | °F | 279.33 | 252.54 | 256.6 | 255.18 | 260.66 |
| Of feed water entering boiler | °F | 200.2 | 191.63 | 198.5 | 202.97 | 198.35 |
| Of escaping gases from boiler | °F | 563.09 | 592.99 | 540.9 | 530. | 556.74 |
| FUEL | | | | | | |
| Size and condition | | FINE, WET. | MEDIUM, DRY | FINE, WET | FINE, WET | |
| Weight of coal as fired | lbs. | 10497 | 8925 | 8356 | 8829 | 9151.7 |
| Percentage moisture in coal | | 15.42 | 13.72 | 15.275 | 15.2 | 14.903 |
| Total weight of dry coal consumed | lbs | 8878 | 7700.5 | 7080 | 7487 | 7786.3 |
| Total ash and refuse | lbs | 1193 | 1300 | 1376 | 1180 | 1262.2 |
| Total combustible consumed | lbs | 7685 | 6400.5 | 5703 | 6307 | 6524.1 |
| Per centage of ash + refuse in dry coal | | 13.248 | 14.099 | 13.55 | 15.7 | 14.149 |
| PROXIMATE ANALYSIS OF COAL | | | | | | |
| Fixed carbon | % | 42.9 | 43.87 | 43.965 | 42.76 | 4337 |
| Volatile matter | % | 30.45 | 30.22 | 29.315 | 29.35 | 29.834 |
| Moisture | % | 15.42 | 13.72 | 15.275 | 15.2 | 14.903 |
| Ash | % | 11.2 | 12.18 | 11.35 | 12.7 | 11.857 |
| FUEL PER HOUR | | | | | | |
| Dry coal consumed per hour | lbs. | 1109.7 | 962.6 | 885. | 935.9 | 973.3 |
| Combustible consumed per hour | lbs. | 960.7 | 800. | 713 | 788.4 | 815.5 |
| Dry coal per sq ft of grate surface per hour | lbs | 27.74 | 24.6 | 21 | 23.4 | 24.185 |
| Combustible per sq ft of water heating surface per hour-lbs. | | .5707 | .4751 | .424 | .48 | 4847 |
| CALORIFIC VALUE OF FUEL | | | | | | |
| Calorific value by calorimeter, per lb of coal dry | B.T.U. | 11700 | 12150 | 12050 | 12300 | 12050 |
| Calorific value by calorimeter, per lb of combustible | B.T.U. | 13480 | 14130 | 13900 | 14225 | 13933 |
| Calorific value by calorimeter, per lb of coal as fired | B.T.U. | 9890 | 10480 | 10200 | 10400 | 10242 |

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# RESULTS OF BOILER TESTS.

| BOILER NUMBER | | 1 | 2 | 3 | 4 | AVERAGE |
|---|---|---|---|---|---|---|
| **QUALITY OF STEAM** | | | | | | |
| Percentage of moisture in steam | | 1.09 | 2.51 | 2.39 | 2.45 | 2.11 |
| Quality of steam | % | 98.91 | 97.48 | 97.61 | 97.65 | 97.89 |
| **WATER** | | | | | | |
| Total weight of water fed to boiler | lbs. | 59312.5 | 58312.5 | 49450 | 52318.5 | 54846.8 |
| Equivalent water fed to boiler at 212°F | lbs. | 62634 | 61927.9 | 52200 | 54928 | 57922.2 |
| Water actually evaporated corrected for quality of steam | lbs. | 58159 | 56846 | 48200 | 51030 | 53559. |
| Factor of evaporation | | 1.056 | 1.0623 | 1.0575 | 1.05 | 1.0564 |
| Equivalent water evaporated into dry steam from and at 212°F. | lbs. | 61444 | 60370.5 | 50955 | 53582 | 56712.8 |
| **WATER PER HOUR** | | | | | | |
| Water evaporated per hour, corrected for quality of steam. | lbs. | 7332 | 7105.8 | 6030 | 6378.9 | 6711.6 |
| Equivalent evaporation per hour from and at 212° | lbs. | 7748 | 7546.3 | 6360 | 6697.8 | 7088. |
| Equivalent evaporation per hour per sq ft. of heating surface | lbs. | 4.6 | 4.482 | 3.78 | 3.9 | 4.1905 |
| **HORSE-POWER** | | | | | | |
| Horse-power developed | | 224.4 | 218.6 | 184.5 | 194 | 205.37 |
| Builders rated horse-power | | 200 | 200. | 200 | 200 | 200. |
| Percentage of builders rated horse-power developed | | 112 | 109 | 92.4 | 97. | 102.5 |
| **ECONOMIC RESULTS** | | | | | | |
| Water apparently evaporated under actual conditions per lb. of coal as fired | lbs. | 5.698 | 6.535 | 5.9 | 5.9 | 5.995 |
| Equivalent evaporation from and at 212° per lb. of coal as fired. | lbs. | 5.968 | 6.76 | 6.1 | 6.07 | 6.227 |
| Equivalent evaporation from and at 212° per lb. of dry coal. | lbs. | 6.97 | 7.85 | 7.2 | 7.15 | 7.29 |
| Equivalent evaporation from and at 212° per lb. of combustible. | lbs. | 8.055 | 9.43 | 8.92 | 8.49 | 8.723 |
| **EFFICIENCY** | | | | | | |
| Efficiency of boiler | % | 57.8 | 64.5 | 62 | 57.7 | 60.5 |
| Efficiency of boiler and grate | % | 57.7 | 62.5 | 57.8 | 56.4 | 58.6 |
| **COST OF EVAPORATION** | | | | | | |
| Cost of coal per ton | $ | 1.35 | 1.35 | 1.35 | 1.35 | 1.35 |
| Cost of fuel for evaporating 1000 lbs. of water under observered conditions. | $ | .1195 | .1032 | .1144 | .1142 | .1128 |
| Cost of fuel for evaporating 1000 lbs. of water from and at 212° | $ | .1143 | .0972 | .1108 | .1118 | .1084 |
| **ANALYSES OF DRY GASES** | | | | | | |
| Carbon dioxide | percent | 2.187 | 2.558 | 1.9 | 2.93 | 2.393 |
| Oxygen | percent | 5.406 | 5.758 | 3.6 | 3.68 | 4.611 |
| Nitrogen (by difference) | percent | 92.407 | 91.654 | 94.5 | 93.39 | 92.996 |

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# RESULTS OF BOILER TESTS

| | SYM | FORMULA | BOILER No 1 | BOILER No 2 | BOILER No 3. | BOILER No 4 | AVERAGE |
|---|---|---|---|---|---|---|---|
| Reading of draft gauge | r | | .3806 | 4282 | .4215 | .3809 | .4029 |
| Temperature of flue | T | | 563.09 | 592.99 | 590.9 | 530 | 556.74 |
| Temperature of outside air | t' | | 74.5 | 84.78 | 75.5 | 78.3 | 78.27 |
| Temperature of boiler-room | t | | 32.85 | 43.16 | 20.5 | 23.66 | 31.54 |
| Weight of coal burned per second lbs. | w | | .364 | .31 | .29 | .307 | .3177 |
| $CO_2$ percent volume | K' | | 2.197 | 2.658 | 1.9 | 2.93 | 2.3393 |
| O + $CO_2$ percent volume | K'+O' | | 7.593 | 8.316 | 5.5 | 6.61 | 6.979 |
| O free percent volume | O' | | 5.406 | 5.758 | 3.6 | 3.68 | 4.611 |
| CO percent volume | U' | | — | — | — | — | — |
| Nitrogen percent volume | N' | $100-(K'+O'+U')$ | 92.407 | 91.654 | 94.5 | 93.39 | 92.996 |
| Dilution coefficient | X | $\frac{N'}{N'-50'}$ | 1.27 | 1.295 | 1.16 | 1.175 | 1.225 |
| Proportional weight | M | $28N'+32O'+28U'+44K'$ | 2853 | 2862 | 2843 | 2835 | 2846.7 |
| Percent oxygen by weight (free) | | $\frac{16O'}{M}$ | .3036 | .323 | .2025 | .2075 | .2841 |
| Percent oxygen by weight (total) | | $\frac{48}{M}(2K'+U'+2O')$ | .0851 | .0934 | .062 | .0685 | .07725 |
| Percent total carbon by weight | | $\frac{12}{M}(U+K')$ | .1118 | .1301 | .0903 | .1012 | .1058 |
| Weight of air per lb. of carbon | W | $11.7X$ | 14.88 | 15.17 | 13.55 | 13.76 | 14.34 |
| Heat units lost per pound of carbon in flue | B | $.238(T-t)(W+1)$ | 1840 | 1958 | 1610 | 1680 | 1772 |
| Efficiency - percent | E | $\frac{Tm'-T'}{Tm'}$ | 74.3 | 72.7 | 76.6 | 76. | 74.9 |
| Percent heat lost in flue | e | $\frac{B}{\text{Calorific Value}}$ | 18.6 | 18.7 | 15.8 | 16.1 | 17.3 |
| Maximum temperature possible in furnace °F | Tm' | $\frac{6000}{K}$ | 3940 | 3860 | 4300 | 4250 | 4087 |
| Volume of air per lb of coal at 32° F cu ft | Vo | $12\frac{5}{6}W$ | 186 | 189.5 | 169.2 | 172. | 179.17 |
| Velocity of air in feet per second | U | $\frac{w\frac{1}{6}(461+T)}{795\pi}$ | 5.9 | 5.28 | 4.195 | 4.56 | SUM 19.935 |
| Head to produce draft from calculated velocity | h | $\frac{U^2}{2g}\left(13+\frac{0121}{m}\right)$ | | | | | 87.9 |
| Head to produce draft from draft gauge reading | h' | $\frac{(461+T)r}{94.7(.0807+\frac{1}{6})}$ | | | | | 31.7 |
| Required height of chimney | H | $\frac{h}{.96\frac{5214.5}{461+t}-1}$ | | | | | 89.6 |
| Actual height of chimney | H' | | | | | | 125 |
| Throttling effect of damper | H'-H | | | | | | 35.4 |

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